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4600 Prospect Avenue

Scene in Bar Mills
Central Steel Co.

We Can Solve Your Problem if It's IN the Steel

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AGATHON ALLOY STEELS

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, October 1922 No. 1

PROGRESS

THE September or Convention issue of TRANSACTIONS completed Volume II. More than twelve hundred pages of reading matter have been included in this volume, which is an increase of approximately sixty-three per cent over the content of Volume I.

While we are of the opinion that quantity is not a substitute for quality we feel that such is not the case with the type of papers which have been presented in Volume II. The quality of the papers which appeared in Volume I were of exceptionally high order, and those appearing in Volume II while of equal calibre cover a somewhat broader field of endeavor. Also the number of papers contributed during the past year has exceeded the number previously received.

It is hoped that the yearly presentation of the Howe medal will inspire more of our capable metallurgists, physicists and chemical engineers to present some of the results of their researches in the realm of science.

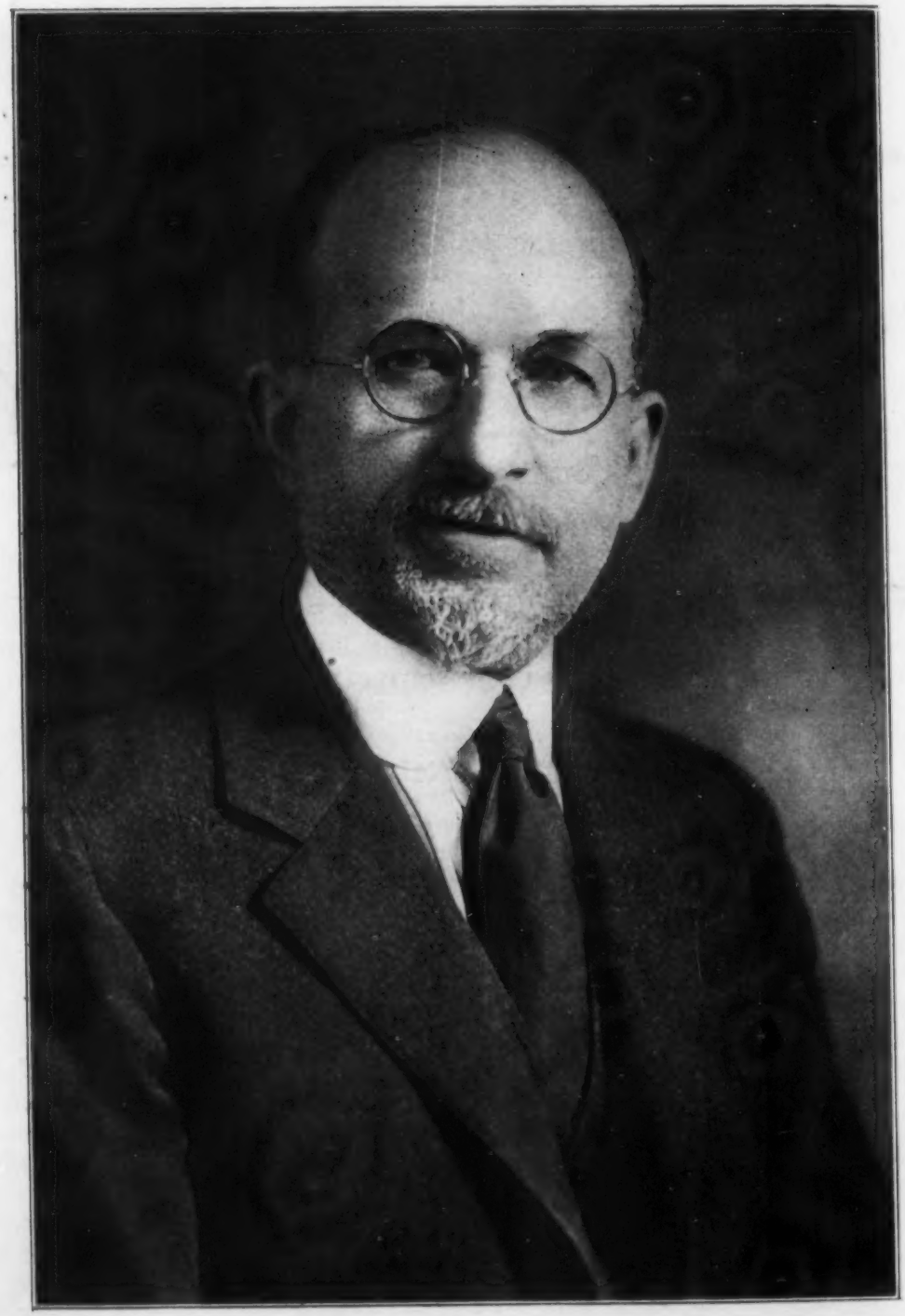
PRACTICE AND THEORY

THE frequent expression "Oh, that is alright in theory but it will not work in practice" is absurd, because a little reflection on the matter will show that whatever will not work out in practice is not right in theory, and that a theory is not wrong simply because it cannot be made to work by the one who formulates it.

In the case of metallurgists or heat treating department supervisors, as in the case of other executives, such as the factory manager or production manager, there are many places where their theories must be put into practice. Upon the skilled worker usually depends the success or failure of a given theory because the "man at the fire" usually has acquired the ability and become trained in the art of heat treating metals whereas his superior has not always had this training. However, the lack of ability on the part of the author of an idea or combination of ideas, to execute his theory does not stamp him as incompetent nor does it mark his theory as non-practical. Many theories which seemingly are not practical have been the foundation of huge commercial developments.

REPORT OF CONVENTION

THE October TRANSACTIONS goes to press on the eve of our fourth annual convention and exposition. The November issue will contain the report of the activities of this the largest of our conventions.



TILLMAN DAVIS LYNCH

National President of the American Society for Steel Treating

Officers of The American Society for Steel Treating

1922-23

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Director, Department of Engineering Research, University of Michigan,
Ann Arbor, Mich.

NEW OFFICERS

THE tellers of election have counted the ballots cast by the membership of the American Society for Steel Treating and the following new officers have been elected: President, T. D. Lynch, research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.; second vice president, W. S. Bidle, president W. S. Bidle Co., Cleveland, Ohio; secretary, W. H. Eisenman, 4600 Prospect Avenue, Cleveland; director, S. M. Havens, assistant treasurer and manager, Ingalls-Shepard Division, Wyman Gordon Company, Harvey, Illinois.

The board of directors of the Society will be composed of the newly elected officers and the following: first vice president, R. J. Allen, metallurgist Rolls-Royce Co. of America, Springfield, Mass.; treasurer, J. V. Emmons, metallurgist Cleveland Twist Drill Co., Cleveland; director, J. J. Crowe, metallurgist Philadelphia Navy Yard, Philadelphia; director, A. E. White, past-president, director engineering research University of Michigan, Ann Arbor, Mich.; director, F. P. Gilligan, past-president, secretary-treasurer Henry Souther Engineering Co., Hartford, Conn.

The new officers will begin their duties at the close of the annual convention of the Society at Detroit, October 2nd to 7th.

August 15, 1922

The report of the tellers is as follows:

To the Secretary,
American Society for Steel Treating,
4600 Prospect Avenue,
Cleveland, Ohio.

The Committee of Tellers begs to submit the results of the balloting

R. J. ALLEN
First Vice President of the Society

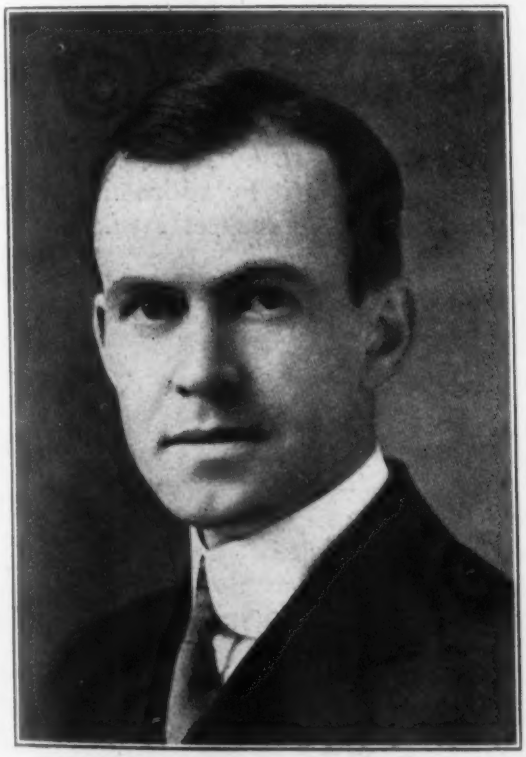
W. S. BIDLE
Second Vice President of the Society

W. H. EISENMAN
National Secretary of the Society

J. V. EMMONS
National Treasurer of the Society

A. E. WHITE
Past President
National Director of the Society

J. J. CROWE
National Director of the Society



F. P. GILLIGAN
Past President
National Director of the Society

S. M. HAVENS
National Director of the Society

by the membership for National Officers of the American Society for Steel Treating.

These ballots were received by the Committee, opened, examined, and counted in the National Headquarters of the Society at 4600 Prospect Avenue, Cleveland, Ohio.

The signature of each voting member written on the outside of the envelope had previously been verified by Secretary, W. H. Eisenman, and found to be correct.

The tabulation of the count is as follows:

	For	Scattering	Not Voting	Defective	Total
For President One Year					
T. D. Lynch	858	7	0	17	882
For 2nd Vice President Two Years					
W. S. Bidle	864	1	0	17	882
For Secretary Two Years					
W. H. Eisenman	864	1	0	17	882
For Director Two Years					
S. M. Havens	861	3	1	17	882

Respectfully submitted,
Committee of Tellers

L. S. COPE,
C. W. SIMPSON,
C. G. SHONTZ, Chairman

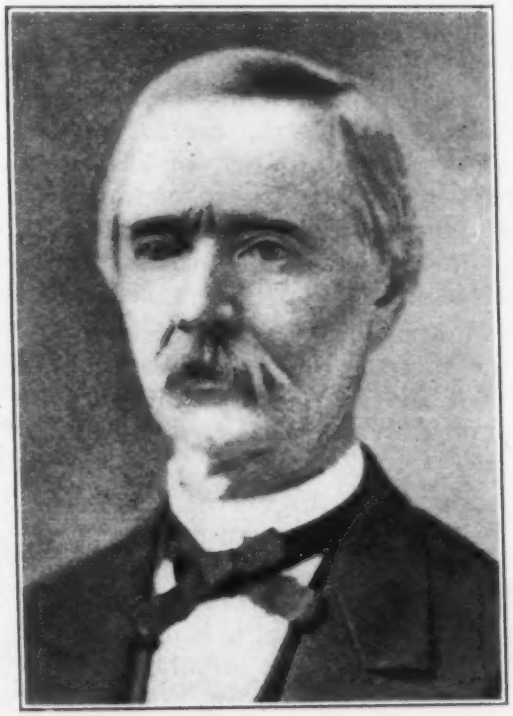
VOLUME TWO TRANSACTIONS INDEX READY

THE index for Volume Two TRANSACTIONS is now ready for distribution. All those who desire a copy of this index may obtain it by addressing their request to W. H. Eisenman, National Secretary, 4600 Prospect Ave., Cleveland.

WILLIAM KELLY

THE following sketch of William Kelly's life and of his claims to the first conception of the pneumatic process for steel making are reproduced here in a slightly abridged form from a very interesting article, "The Romance of Steel and Iron in America," by Herbert N. Casson, in Munsey's Magazine for April 1906.

In 1846 William Kelly and his brother bought the Suwanee Iron Works, near Eddyville, Kentucky. Kelly's father was a well-to-do landowner in Pittsburgh, where it is said that he erected the first two brick houses in the city. At the time when William Kelly began to make iron he was thirty-six years old, a tall, well-set-up, muscular, energetic man, with blue eyes and close-cropped beard. In inventiveness his brain



WILLIAM KELLY

ranked high; in business ability, low. He had left a commission business and become an iron maker mainly to carry out a process which he had invented, by which larger sugar kettles were to be made. The "Kelly kettles" became well known among the Southern farmers.

He had married Miss Mildred A. Gracy, of Eddyville, and secured the financial backing of his wealthy father-in-law. His iron plant was a fairly good one, close to high-grade ore, and needing the work of about three hundred negro slaves. Mr. Kelly was strongly opposed to slavery, and tried to escape from being a slaveholder by importing Chinese. He was the first employer in this country to make this experiment, and found it successful; but international complications prevented him from putting it into practice on a larger scale.

Kelly's first aim was to make good wrought iron for his Kettles

and for customers in Cincinnati. His iron was refined in what was called a "finery fire,"—a slow, old-fashioned process which used up quantities of charcoal.

In a year all the wood near the furnace had been burned, and the nearest available source of supply was seven miles distant—a fact with which the unbusinesslike Kelly had not reckoned. To cart his charcoal seven miles meant bankruptcy, unless—he could invent a way to save fuel.

One day he was sitting in front of the "finery fire" when he suddenly sprang to his feet with a shout, and rushed to the furnace. At one edge he saw a white-hot spot in the yellow mass of molten metal. The iron at this spot was incandescent. It was almost gaseous. Yet there was no charcoal—nothing but the steady blast of air. Why didn't the air chill the metal? Every iron maker since Tubal-Cain had believed that carbon and oxygen had an affinity for each other. They knew what air was and what iron was, and like a flash the idea leaped into his excited brain—there is no need of charcoal; air alone is fuel.

It was as simple as breathing and very similar, but no human mind had thought of it before. When the air is blown into the molten metal the oxygen unites with the impurities of the iron and leaves the pure iron behind. Oxygen—that mysterious element which gives life to all creatures, yet which burns up and destroys all things; oxygen, which may be had without money in infinite quantities—was now to become the creator of cheap steel.

Kelly was carried away by the magnitude of his idea. His unrestrained delight, after months of depression, amazed every one in the little hamlet. Most of his neighbors thought him crazy. Only three listened with interest and sympathy—two English iron workers and the village doctor.

At first Kelly snapped his fingers at opposition. "I'll prove it publicly," he said. At his invitation a number of jesting iron makers from Western Kentucky gathered around his furnace the following week, and Kelly, caring nothing for patents, explained his idea and gave a demonstration of it. Air was blown through some melted pig iron, agitating it into a white heat, to the amazement of the brawny onlookers. A blacksmith seized a piece of the refined iron, cooled it, and with his hammer produced in twenty minutes a perfect horseshoe. He flung it at the feet of the iron-men, who could not believe their eyesight, and seizing a second scrap of iron, made nails and fastened the shoe to the foot of a nearby horse. Pig iron, which cannot be hammered into anything, had been changed into malleable iron, or something very much like it, without the use of an ounce of fuel.

Surely, the thing was too absurd. Seeing was not believing. "Some crank'll be burnin' ice next," said one. The iron-men shook their heads and went home to boast in after years that they had seen the first public production of "Bessemer" steel in the world.

Kelly called his invention the "pneumatic process," but it became locally known as "Kelly's air-boiling process." He proceeded at once to refine his iron by this method. He sent his steel, or refined iron, or whatever it was, to Cincinnati, and no flaws were found in it. Years before Mr. Bessemer had made any experiments with iron there were

steamboats on the Ohio River with boilers made of iron that had been refined by Kelly's process.

But now came a form of opposition that Kelly could not defy. His father-in-law said: "Quit this foolishness or repay the capital I have advanced." His Cincinnati customers wrote: "We understand that you have adopted a new-fangled way of refining your iron. Is this so? We want our iron made in the regular way or not at all."

About the same time Kelly's ore gave out. New mines had to be dug. Instead of making ten tons a day, he made two.

He surrendered. He became outwardly a level-headed, practical, conservative iron maker and won back the confidence of his partners and customers. Then one night he took his "pneumatic process" machinery three miles back into a secluded part of the forest and set it up. Like Galileo, he said: "Nevertheless, air is fuel!" No one knew of this secret spot except the two English iron-workers whom he brought out frequently to help him.

Under such conditions progress was slow. By 1851 his first converter was built—a square, brick structure, four feet high, with a cylindrical chamber. The bottom was perforated for the blast. He would first turn on the blast and then put in melted pig iron with a ladle. About three times out of five he succeeded. The greatest difficulty was to have the blast strong enough, otherwise the iron flowed through the airholes and clogged them up.

His second converter was made with holes in the side, and worked better. He discovered that he could do ninety minutes work in ten, and save further expense in fuel. One improvement followed another. In all he built seven converters in his backwoods hiding place.

In 1856 Kelly was told that Henry Bessemer, an Englishman, had taken out a United States patent for the "pneumatic process." This aroused Kelly's national pride more than his desire for a monopoly, and he at once filed in the Patent Office his claims to priority of invention. The Patent Office was convinced and granted him United States Patent No. 17,628, declaring him to have been the original inventor.

Then came the panic of 1857, and Kelly was one of the thousands who topped over into bankruptcy. To get some ready money, he sold his patent to his father for a thousand dollars. Not long afterwards, the elder Kelly died and willed his rights to his daughters, who were shrewd, businesslike women. They regarded their brother William as a child in financial matters and refused to give him his patent. After several years of unjustifiable delay, they transferred it to Kelly's children. And so, between his relations and his creditors, Kelly was brought to a standstill.

But even at the lowest point of defeat and poverty, he persevered. Without wasting a day in self-pity, he went at once to the Cambria Iron Works, at Johnstown, Pa., and secured permission from Daniel J. Morrell, the general superintendent, to make experiments there.

"I'll give you that corner of the yard and young Geer here to help you," said Morrell.

In a short time Kelly had built his eighth converter,—the first that really deserved the name,—and was ready to make a public demonstration. About two hundred shopmen gathered around his queer-looking apparatus. Many of them were puddlers, whose occupation would be gone if Kelly succeeded. It is often fear that makes men scoff, and the

puddlers were invariably the loudest in ridiculing the "Irish crank."

"I want the strongest blast you can blow," said Kelly to Leibfreit, the old German engineer.

"All right," answered Leibfreit. "I gif you blenty!"

Partly to oblige and partly for a joke, Leibfreit goaded his blowing engine to do its best, hung a weight on the safety-valve, and blew such a blast that the whole contents of the converter went flying out in a tornado of sparks. This spectacular display filled the hundred shopmen with delight. For days you could hear in all parts of the works roars of laughter at "Kelly's firewirks." In fact, it was ten years' joke in the iron trade.

In a few days Kelly was ready for a second trial, this time with less blast. The process lasted more than half an hour and was thoroughly unique. To every practical iron maker, it was the height of absurdity. Kelly stood coatless and absorbed beside his converter, an anvil by his side and a small hammer in his hand. When the sparks began to fly, he ran here and there, picking them up and hammering them upon his anvil. For half an hour every spark crumbled under the blow. Then came one that flattened out, like dough—proving that the impurities had blown out. Immediately he tilted the converter and poured out the contents. Taking a small piece, he cooled it and hammered it into a thin plate on his anvil, proving that it was not cast iron.

He had once more shown that cold air does not chill molten iron, but refines it with amazing rapidity if blown through it for the proper length of time. His process was not complete, as we shall see later, but subsequent improvements were comparatively easy to make. Bessemer, by his own ecorts, did not get any better "steel" in 1855 than Kelly had made in 1847.

For this exact account of Kelly's achievements I am indebted to Mr. J. H. Geer, who was his helper at Johnstown, and to others who were eye-witnesses of his earlier success in western Kentucky.

As early as 1861 Capt. E. B. Ward, of Detroit, and Z. S. Durfee, of New Bedford, obtained control of the patents of William Kelly, who had previously successfully experimented with the pneumatic process at Eddyville, where he owned the Eddyville Iron Works. In 1861 Mr. Durfee went to Europe to study the Bessemer process. During his absence Captain Ward invited William F. Durfee, also of New Bedford, and a cousin of Z. S. Durfee, to erect an experimental plant at Wyandotte, Mich., for the manufacture of pneumatic steel, and this work was undertaken in the latter half of 1862.

In May, 1863, Daniel J. Morrell, of Johnstown, and William M. Lyon and James Park, Jr., of Pittsburgh, having become partners of Captain Ward and Z. S. Durfee in the control of the patents of Mr. Kelly, the Kelly Pneumatic Process Company was organized, Mr. Kelly retaining an interest in any profits which might accrue to the company. It was resolved to complete the experimental works already undertaken and also to acquire the patent in this country of Mr. Mushet for the use of spiegeleisen as a recarburizing agent. This patent was granted in England in 1856 and in this country in 1857. Mr. Z. S. Durfee accordingly went to England to procure an assignment of Mr. Mushet's patent. The latter purpose was effected on the 24th of October, 1864, upon terms which admitted Mr. Mushet, Thomas D. Clare and John N. Brown of

England, to membership in the Kelly Process Company. On September 5, 1865, the company was further enlarged by the admission to membership of Charles P. Chouteau, James Harrison and Felix Valle, all of St. Louis. In September, 1864, William F. Durfee succeeded in making Bessemer steel at the experimental works at Wyandotte. This was the first Bessemer steel made in the United States.

Kelly remained at Jownstown for five years. By this time he had conquered. His patent was restored to him, and Mr. Morrell and others bought a controlling interest in it. He was now honored and awarded. The "crank" suddenly became a recognized genius. By 1870 he had received thirty thousand dollars in royalties; and after his patent was renewed he received about four hundred and fifty thousand more. After his process had been improved and widely adopted, Kelly spent no time claiming the credit or basking in the glory of his success. No man was ever more undaunted in failure and more modest in victory. He at once gave all his attention to manufacturing high-grade axes in Louisville, and founded a business which is today being carried on at Charleston, West Virginia, by his sons.

When more than seventy years of age, he retired and spent his last days at Louisville. Few who saw the quiet, pleasant-faced old gentleman in his daily walks knew who he was or what he had accomplished. Yet, in 1888, when he died, it was largely by reason of his process that the United States had become the supreme steel-making nation in the world. He was buried in the Louisville cemetery.

Th new process was perfected by a third inventor, Robert F. Mushet, a Scotchman. He solved a problem which had baffled both Kelly and Bessemer—how to leave just enough molten metal to harden it into the required quantity of steel. Instead of frantically endeavoring to stop the process at exactly the right moment, Mushet asked:

"Why not first burn out all the carbon, and then pour back the exact quantity that you need?"

This too, was a simple device, but no one had thought of it before. Since then other improvements have been added by Holley, W. R. Jones, Reese, Gilchrist and Thomas.

The new metal was soon called by the name of "Bessemer steel." Strictly speaking, it was not steel in the original use of the word. It was a new substance, very much like wrought iron. It was not hard enough to serve for all purposes. For knives, for springs, for hammers, for a thousand finer uses, steel must still be made by slower and more careful methods. The Bessemer product does the rougher work, where quantity and cheapness are essential. In an axe, for instance, the cutting edge is made of crucible steel and the rest of Bessemer steel. All the steel rails, the great beams and girders that make our skyscrapers and bridges, the plates of steamships, the wire, nails, tubes, freight-cars and innumerable things, great and small, are made of the new metal that was first produced less than sixty years ago.

It is probable that one reason for the naming of Bessemer steel was the fact that true steel was then selling at three hundred dollars a ton. The new metal might have been less highly esteemed had it been announced merely as a modified form of iron.

In 1870, both Kelly and Bessemer applied to the United States Patent Office to have their patents renewed. The Commissioner of

Patents refused to extend Bessemer's, stating that he had no right to a patent in the first place, but Kelly's was extended for seven years, on the ground that he had not yet received sufficient remuneration for his invention. As soon as it was known that Kelly's patent was to be renewed the Patent Office was fairly mobbed by objectors. Never before had there been such opposition to the renewal of a patent. The steel makers and the railroad men united in a chorus of protest. The dread of paying higher royalties drove them to attack Kelly's claims. Bessemer, whose right to royalties was now at an end, was lauded as the original inventor, while Kelly was vilified as an interloper. Out of this opposition sprang the exaltation of Bessemer and the belittling of Kelly, which deprived America of the credit for one of the world's greatest inventions.

Kelly's claim is supported not only by the United States Patent Office but by the most eminent authorities. "Kelly in America, Bessemer, Mushet and Goransson in Europe, discovered and developed the pneumatic process of treating pig iron," says Robert W. Hunt, the veteran steel expert of Chicago. James Park, one of the Pittsburgh "fathers of steel," declared that "The world will some day learn the truth and in ages to come a wreath of fame will crown William Kelly, the true inventor of the Bessemer process." Even an English writer, Zerah Colburn records that "the first experiments in conversion of melted cast iron into malleable steel were made in 1847 by William Kelly." And the greatest living authority on the history of American iron and steel—James M. Swank, who has been the secretary of the American Iron and Steel Association for a generation—says:

"Mr. Kelly claims the discovery of the pneumatic principle of the Bessemer process several years before it dawned upon the mind of Mr. Bessemer, and the validity of this claim cannot be impeached."

And so Henry Bessemer, who was second in the race, received ten million dollars, world-wide fame and knighthood; while William Kelly, who was first, received half a million dollars and comparative oblivion Kelly was not to any degree embittered by his country's disregard of him. He had an unwavering conviction that everything would he made right. Shortly before his death he said to his children:

"The day will come when some one will do me justice."

It remained for the Detroit Chapter of the American Society for Steel Treating to commemorate the achievement of the early pioneers in the development of the process that caused the United States to become the supreme steel making nation in the world.

DURALUMIN
A DIGEST OF INFORMATION

By Horace C. Knerr

Abstract of Paper

An alloy as light as aluminum but as strong as mild steel, equal in strength to high grade alloy steel of the same structural weight, ductile, resistant to corrosion, suitable for a large variety of manufacturing purposes, easily drawn, machined, and forged, taking a high polish, and which derives its remarkable properties from heat treatment, is one which must have the attention of physical metallurgists, designers and users of high grade metals of construction.

Duralumin is a comparatively new arrival in the field of metallurgy, but its interesting and valuable properties have earned for it so much publicity, that even the layman is familiar with the name and at least some of the characteristics of this remarkable aluminum alloy. Technical and popular papers on the subject have been numerous but scattered, with the latter not always entirely accurate. The aim of the present paper is to present in concise, but comprehensive form, the salient facts concerning duralumin. It includes discussions of composition, chemical and physical constitution, manufacture, casting, forging, heat treating mechanical properties, resistance to corrosion and industrial applications.

Every effort has been made for accuracy as well as brevity. Data have been compiled from a considerable number of references, from experiments conducted by the writer and from observation of the practical application of the material in the construction of aircraft of both the airship (lighter-than-air) and airplane (heavier-than-air) types. Compilation has been done under limitations as to time. The author will greatly appreciate the correction of any errors that may be noted.

Historical

THE behavior and properties of the alloy known as "duralumin" were first observed by Alfred Wilm during his investigations from 1903 to 1911, (12)* in the development of a material of construction for the Zeppelin airships. It was made at the Durener Metallwerks, Duren, Germany.

Aluminum rich alloys with magnesium and copper have become well known in Europe and America during the past twelve years under the name of "duralumin." (8).

Its manufacture was taken up by Vickers, Ltd., in England, prior to the war.

Manufacturer's using the name in the United States claim the sole right to do so under patents held by the Chemical Foundation, Inc.,

*Figures in parenthesis refer to sources of information, listed under Bibliography.

A paper presented at the Detroit Convention October 2-7. The author, is metallurgist, Naval Aircraft Factory, Philadelphia.

of N. Y. Products having almost the same composition and physical properties as the latter, but the subject of different patents, are manufactured under other trade names or symbols, such as "17S" and "Lynite 400". These alloys might perhaps be grouped under the broader term "duralumins".

The commercial manufacture of duralumin in the United States dates back to about 1919, however, rapid progress has been made and a product of excellent quality is now available. For convenience the term duralumin will be used thruout this paper, but the text applies as well to those alloys having substantially similar composition.

Composition

Compositions given for duralumin vary considerably, but the following limits are representative:—

Copper	3.5 to 4.4 %
Magnesium	0.2 to 0.75
Manganese	0.4 to 1.0
Aluminum (minimum)	92.00

Iron and silicon, as impurities, under 0.6% each.

A typical analysis is:—

Copper	Magnesium	Manganese	Iron	Silicon	Aluminum
3.90	.60	.50	.40	.25	94.35

Tin, lead, nickel, zinc, nil, or trace.

The composition is modified for special purposes. Where severe drawing or deformation is required, the copper content may be reduced and the manganese omitted entirely, giving a material of lower tensile strength but increased ductility. The addition of small quantities of chromium is said to improve the burnishing qualities.

Manufacture

The manufacture of duralumin includes the following steps:— (15)

1. Preparation of the alloy
2. Casting the ingot
3. Hot rolling or cogging into blooms, billets or slabs
4. Hot or cold rolling to sheet, strip, bar, etc.
5. Heat treating (and ageing)
6. (Sometimes) Working to special shape while plastic, immediately after quenching, before ageing
7. (Sometimes) Cold working, after heat treatment and ageing, to increase hardness and strength.

Casting the Ingots

Details of manufacture are difficult to obtain, but the practice may be described briefly as follows:

The constituents are melted in an iron crucible, beginning with aluminum ingot of 99 per cent purity, adding 50:50 copper-aluminum alloy for the copper, a 90:10 aluminum-manganese alloy for the manganese, and finally, just before pouring, a 90:10 aluminum-magnesium alloy for the magnesium. Adding straight magnesium in lumps in the ladle, just before pouring, has also been recommended.

Melting and pouring are done at the lowest possible temperatures, 1275-1330° F. (690-710° C.) has been given for the latter. An iron ladle

is used, externally insulated to retain the heat. The metal is poured very slowly into iron molds, permitting solidification to progress from the bottom upward, while pouring, so that only the top layer of metal is liquid. This minimizes shrinkage cavities, porousness and segregations. There is only about 5 per cent head. The ingots are brick-shaped and weigh 50 to 75 pounds.

Sheet, Strip and Channels

Duralumin is used principally in sheet form, or products derived from sheet. The ingots are reheated to about 840° F. (450° C.) for rolling, the furnace temperature being about 900° F. (480° C.) Overheating must be avoided, as the metal is hot short. Rolls should be warmed to remove chill and are lubricated in the ordinary manner. Ingots are rolled to slabs ⅜ to ¼ inch thick at the first rolling, and later cold rolled to finished gage. There should be only slight cracking at the edges. The sheets may be annealed two or three times during cold rolling. Sheets which are required in the heat treated condition are generally given one or more passes through the rolls (cold) to flatten them after quenching. Sheets may be slit into strips for the production of profile shapes, such as channels, etc. These strips are coiled, quenched, straightened, immediately rolled to the desired section and then allowed to age.

Bar Stock, Rod, Wire and Tube

Bar stock, rod and wire are also used in quantity; rivets being made from the latter. Bars up to 2½ inches in diameter are made by extrusion, the process being similar to that used for brass. Bars are also forged, especially above 2½ inches in diameter. (6) Heavy angle and other sections are extruded. Seamless tubing has been produced to a considerable extent in Germany and England, but its production in this country is just beginning. The oblique rolling method of making seamless tube blanks is not successful with duralumin. Blanks and heavy tubes are produced by extrusion, and thin walled tubes by solid drawing. For extrusion, ingots are about 6 inches in diameter by 12 inches long. The temperature is approximately 950° F. (510° C.).

Cold working duralumin which has been heat treated and aged has much the same effect as cold working steel, increasing the hardness and tensile strength at the expense of ductility.

Remelting Scrap

Duralumin scrap when properly remelted and forged will have properties nearly if not quite, as good as the original metal. Cast iron or steel crucible is used. Gas, oil, coke or electric heat may be used, but furnace gases should be excluded from the crucible. The scrap is heated to a plastic state and kneaded well with an iron rod. When all is plastic, the temperature is raised to between 1290-1380° F. (700-750° C.) held for a few minutes, stirred, skimmed, allowed to stand for about one minute and casted. Before the first skim, a little zinc chloride (1 ounce to 50 pounds of scrap) should be stirred in as a flux. Temperatures should be held as low as possible, and the metal should not be kept hot longer than necessary.

Ingots should be cast in iron molds, as described under "manu-

facture" and the molds should not be larger than necessary. The ingots should be heated to about 660° F. (350° C.) and forged with light blows into bars, as outlined under forging.

Forging

Duralumin makes excellent plain or die forgings. (20) (6) (16) Forging temperatures are given from 660-840° F. (350-450° C.) by various authorities. This is below the color range and pyrometric control is essential. Heating may be done in a salt bath, or in a muffle or semi-muffle furnace. Contact with an open flame damages the metal. Overheating causes brittleness, as the metal is hot short above 840 degrees Fahr.

Billets are heated much more rapidly and probably more uniformly in the salt bath than in a muffle furnace. A film of salt will adhere when the parts are withdrawn, but will not, as a rule, interfere with the forging. It may be removed by a quick rinse in hot water. Forgings may become overheated and crack, due to too severe working. Light blows and gradual reductions are preferable. The use of a small belt driven drop hammer has been recommended. About the same amount of power is required as in forging steel, and similar dies are used. When the metal becomes cold it gives a decided metallic ring.

Castings

Duralumin is not used for castings. It has a persistent tendency to porosity, and its physical properties, although improved by heat treatment, are inferior to other high grade aluminum casting alloys. The properties of cast duralumin are given by Grard (10) as follows:—

	Tensile strength pounds per square inch
Sand cast	15,600
Sand cast and quenched	19,900
Chill cast	14,200
Chill cast and quenched	21,300

Elongation and shock resistance is approximately zero in all cases. The superior properties of duralumin are obtained only from the worked material.

Heat Treatment

Duralumin bears the same relation to aluminum that high-strength alloy steel bears to soft iron or mild steel, and similarly, its superior qualities depend upon proper heat treatment. The behavior of duralumin under heat treatment is in outward appearance, strikingly different from that of steel, although fundamentally, it is in many ways similar, as will be discussed under (Theory of Heat Treatment.)

Heat treatment consists simply in heating to about 932 degrees Fahr. holding until saturated and quenching. This must be followed by a period of "ageing" at room temperature. Immediately after quenching, duralumin is soft. Its hardness and tensile strength then increase, at first rapidly, and then slowly for a period of 4 to 10 days, when it has attained its maximum strength and hardness. Duralumin softens greatly when heated to the quenching temperature, and should therefore be properly supported in the furnace, and handled with care in quenching, to avoid deformation. However, on account of its soft

condition immediately after quenching, it may easily be straightened at this time, should deformation occur. Heat treatment, to produce maximum physical properties, is sometimes called "tempering" to distinguish it from the process of annealing. (See Annealing)

Heating

Heating may be done in an electric, gas, oil or even coal fired muffle or semi-muffle furnace provided proper temperature control and uniformity are assured. Contact with an open flame damages the metal. A salt bath composed of a mixture of approximately equal parts of sodium nitrate and potassium nitrate is the most approved method of heating because of the temperature uniformity, and the rapidity with which the parts are heated. A thin layer of the salts will adhere to parts when they are withdrawn, but this is quickly washed off when quenched in water, especially in hot water. It is important that the salt be entirely removed from the metal to avoid subsequent corrosion. A tank made

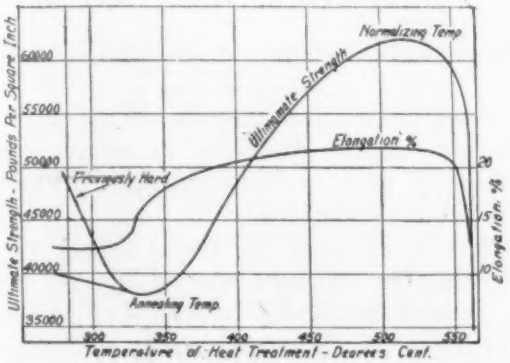


Fig. 1—Variation in strength of Duralumin with the Temperature of Heat Treatment. (After Vickers, Ref. 6.)

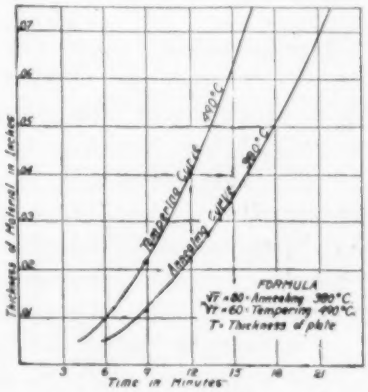


Fig. 2—Curves for annealing and tempering Duralumin for plates of various thickness, giving the time allowance in the salt bath.

of boiler plate; welded or riveted and caulked at joints, heated by gas or oil flame is suitable for the salt bath. (Carbonaceous fuels, such as coke, and charcoal, should never be used in heating the salt bath, as leakage or spilling of the nitrates into this fuel will cause violent combustion or explosion). The same nitrate bath may be used at the lower temperatures required for annealing. The furnace or salt bath may be at the specified maximum quenching or annealing temperature, but not higher, when the work is inserted. Preheating is not required.

No scale is produced in heating duralumin, either in the furnace or salt bath, although a slight discoloration occurs, which is purely superficial.

Quenching Temperature

The physical properties obtained by heat treatment improve with higher quenching temperature up to about 986° F. (530° C.) Heating above 1004° F. (540° C.) causes rapid deterioration. (See Theory of Heat Treatment). For commercial purposes, the limits 915-950° F (490-510° C.) are generally used; 930-970° F. (500-520° C.) may be used if very close regulation is assured. Accurate pyrometric control is essential.

Base metal couples may be inserted in the bath, with or without a thin steel tube sheath. The variation of tensile strength and elongation with quenching temperature are shown in Fig. 1. (6).

Time of Heating

The time of heating, or "soaking", must be sufficient to insure that the work has come to the desired temperature throughout. Additional soaking is not harmful, except that thin sections are likely to blister if left too long in the nitrate bath. Parts will heat more rapidly in the bath than in the furnace. The time in the salt bath for various sections is, roughly as follows:—

Rivets, thin sheet and strip.....10 to 15 minutes
Bars and thick sections.....30 minutes to 1 hour
Heavy forgings and bars.....2 hours

Vickers (6) give the following formulas for the minimum time in minutes in the *salt bath*:

For heat treating..60 times square root of diameter or thickness in inches
For annealing.....80 times square root of diameter or thickness in inches

This works out for sheet as shown in the curves, Fig. 2. The time required for heating in an electric muffle furnace is much longer than in the salt bath. A definite rule is not at the moment available, but the results of the following tests are instructive:

(a) Specimens of sheet duralumin 1/16 and 1/8 inch thick, heated in an electric muffle furnace for 20 minutes showed very slightly lower tensile properties than specimens of similar material heated for the same period in a nitrate bath, the temperature in both cases being 932 degrees Fahr. This indicates that 20 minutes is a minimum time for heating material of this thickness in a furnace; 35 to 40 minutes would be a safer allowance, with a proportionately longer time for thicker parts.

(b) A duralumin ingot 2¼ inches in diameter and 11 inches long having an axial hole ¾ inch in diameter and 8 inches deep into which a thermocouple was inserted, was heated in an electric muffle furnace and in a nitrate bath, to determine the time required to heat from room temperature to the maximum in each case. The heating curves are shown in Fig. 3. The core of the ingot reached the temperature of the bath (875 degrees Fahr.) in approximately 15 minutes; whereas it was still 50 degrees Fahr. below the furnace temperature (830 degrees Fahr.) after 90 minutes; a ratio of 6 to 1. It is evident that the metal absorbs heat much faster from the liquid salt than from the air.

Quenching

Water is generally used as a quenching medium, and is practically essential when the salt bath is used in heating, in order to dissolve the adhering salts. Quenching in boiling water is generally recommended as it is believed to give the best physical properties after ageing and it is less likely to cause distortion or cracking, due to cooling stresses than cold water. Violent spattering occurs when parts are quenched in boiling water.

Quenching in cold water, that is, at room temperature, (about 60 degrees Fahr.), leaves the material in a softer and more easily work-

able condition, and experience has shown that the physical properties are little if any, inferior to those obtained by quenching in boiling water. There is also some evidence that resistance to corrosion is improved by quenching in cold water (See Corrosion). Ordinary light quenching oil is a satisfactory quenching medium when a furnace is used in heating. In some cases the same equipment used in heat treating steel can therefore be used for duralumin. In heat treatment, the parts should be quenched immediately after removal from the furnace, with minimum loss of temperature. An increase of the temperature of the quenching bath up to 300° F.(150° C.) is said to give a slight improvement in tensile properties, but there is no further improvement up to 395° F. (200° C.) while higher temperatures are detrimental. (1)

Various Quenching Mediums

Experiments were carried out (20) to determine the tensile properties produced in duralumin sheet by quenching in various mediums, including air cooling. Tensile speciments 1/16 and 1/8 inch thick

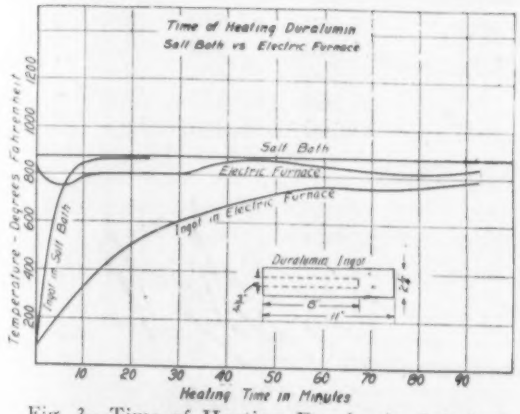


Fig. 3—Time of Heating Duralumin Salt bath versus Electric furnace. Salt bath tank, 4 feet 3 inches by 18 inches by 21 inches. Hoskins muffle furnace 5 inches by 7 inches by 14 inches.

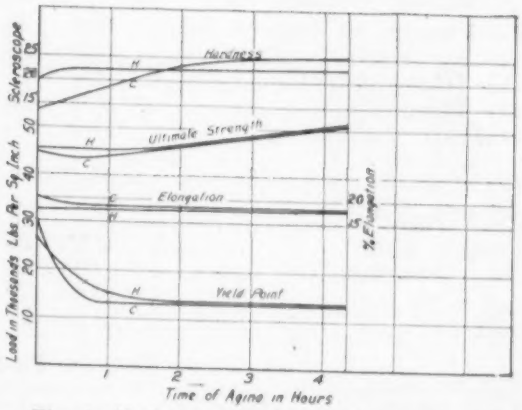


Fig. 4—Variation in mechanical properties with time after quenching in hot and cold water. 1/8-inch duralumin sheet held 20 minutes in nitrate bath at 932 degrees Fahr.

were used, care being taken to insure uniformity of material. These were heated to 930 degrees Fahr. in an electric muffle furnace and quenched in cold water (60 degrees Fahr.) boiling water, quenching oil, still air, and in the direct blast of a 12-inch electric fan. Hardness and tensile tests are summarized in Table I.

The tensile properties obtained from the various mediums differ little, and practically all meet the specifications. Very slow cooling (as in the furnace) from the quenching temperature anneals duralumin. The cooling of the tensile specimens in air was evidently sufficiently rapid to produce the effects of heat treatment. Larger parts would cool more slowly and would doubtless have correspondingly lower tensile properties.

The scleroscope hardness readings indicate the progress of ageing. A comparison of the hardness produced immediately (5 minutes) after quenching is interesting. Cold water gave the softest, most workable, material, and boiling water the hardest. The ultimate hardness was nearly the same, for each thickness. The specimens were allowed to remain in the boiling water for one minute. Cold water is shown to

be the most desirable medium where severe cold working is to be done. The effect of the quenching medium on the resistance to corrosion was very pronounced (20) and is discussed under Corrosion.

Ageing

Ageing after quenching proceeds normally at ordinary room temperature, 70 degrees Fahr., and will be practically complete in four days, although there is a slight improvement for about six additional days. Ageing is accelerated with increase of ageing temperature up to about

Table I

Quenching Mediums.

Tensile tests (aged 10 days)

Quenching medium	Scleroscope hardness after: — 5 minutes	2 days	5 days	Yield point pounds per square inch	Ultimate strength pounds per square inch	—Elong.— % 2 inches	% 4 inches
Specimens 1/6-inch Thick							
Cold water, 60 degrees Fahr.	14.4	26.6	26.8	36,560	61,640	18.9	16.6
Boiling water	20.8	25.4	26.2	35,640	61,500	19.1	17.6
Oil (Houghton's)	16.4	26.0	27.0	35,300	61,400	18.9	17.3
Air blast	18.0	26.0	27.0	35,560	59,330	18.0	15.4
Still air	18.0	25.0	26.0	33,000	58,900	18.3	16.0
Specimens ⅛-inch Thick							
Cold water	15.2	29.6	29.6	38,700	61,000	19.2	16.9
Boiling water	23.0	27.4	28.0	35,900	61,740	19.8	17.2
Oil (Houghton's)	19.4	28.4	28.6	38,300	61,700	19.8	15.7
Air blast	19.0	27.0	28.0	34,250	58,580	17.5	16.0
Still air	20.0	26.0	27.0	36,200	58,050	18.0	15.0

Tensile Test Requirements

Yield stress	25,000 pounds per square inch minimum
Ultimate stress	55,000 pounds per square inch minimum
Elong. in 2 inches	18% minimum

300 degrees Fahr. but above that temperature, the physical properties are impaired. Heating to 212 degrees Fahr. for several hours is about as effective as several days of ageing at room temperature. This is easily accomplished by allowing the material to remain in the boiling water in which it is quenched. Changes of physical properties with time of ageing are shown in Figs. 4 and 5.

Annealing

Duralumin is annealed by heating to between 660 and 715 degrees Fahr. followed by quenching or by cooling in air or in the furnace. This leaves the material in a soft and workable condition, even softer than when freshly tempered and unaged. The annealed material when furnace cooled will remain soft indefinitely, or harden only slightly when more rapidly cooled, so that the necessity for immediate working, as after tempering, is avoided. Severe cold working will cause hardening, as in other metals, but this is removed by re-annealing, which may be repeated a number of times without ill effects. Annealed material must finally be heat treated (tempered) to give it the required high

tensile properties. Soaking at the annealing temperature and slow cooling are essential to obtain the softest metal. Annealing may also be accomplished by very slow cooling from the quenching temperature.

Properties

General

Duralumin has now been in use abroad for approximately a decade. During this time the reliability and permanence of its properties as a material of construction have become quite well established. The peculiar behavior of duralumin in hardening after heat treatment, gave rise, when the metal was first introduced to some doubt as to the permanence and stability of the material in the hardened condition. Tests on samples of the material which had been exposed in the open for about eight years showed the same strength as obtained within a week after heat treatment. (6) Table II shows some interesting properties of duralumin.

Either in the ingot (chill cast) or as rolled or forged duralumin has

Table II
Some Physical Constants of Interest

Specific gravity	2.80 to 2.85 (4)
Weight, pounds per cubic inch	.100 to .102
Weight, pounds per cubic foot	173 to 176
Melting range	1000-1200° F. (540-650°C.)
Cofficient of linear expansion, per degree Cent	.0000226 (4) (6)
Thermal conductivity (silver 100)	31
Specific heat	.214 (6)
Electrical resistivity (12)	
Annealed state	3.43 microhms per centimeter cube
Heat treated state	4.73 microhms per centimeter cube

Duralumin is non-magnetic.

a remarkably clear, silvery tone when struck. Heat treated duralumin takes a fine polish, which is apparently permanent indoors and which does not tarnish in handling.

Duralumin siezes badly when in friction with itself. It seems to work well in bearing contact with brass, and has been used with success (15) as a bearing metal in contact with hardened steel. Threaded parts, such as bolts, fittings, etc., are best used in conjunction with another metal to avoid seizing. Lubricants help to some extent to prevent seizing, but their effect is soon destroyed in the presence of moisture, which causes corrosion, or gasoline and other solvents, which remove the lubricant.

Mechanical Properties

The following values shown in Table III are taken from technical data for duralumin sheet issued by an American manufacturer. (16)

These data apply to sheets up to 18 inches wide and ranging in thickness from .010 to .625 inch in the annealed or heat treated state and up to 14 inches wide and .016 to .125 inch thick in the hard rolled condition. The heat treated material can be bent 180 degrees over a mandrel four times the thickness of the sheet, and will withstand slight forming operations. The annealed material may be drawn; spun, stamped and formed into a variety of shapes, like brass and mild steel.

Heat treatment of annealed material gives it the same properties as listed under "Heat Treated". Either heat treated or hard rolled material may be annealed.

The hard rolled material is very hard, strong and springy and will not stand bending or forming. It machines and threads well. The strength of duralumin, is as in most metals, affected by the amount of working it has received, light sections, having a higher unit strength than thick ones. The thickness of the section also influences the results of heat treatment.

The following is a fair specification for sheet less than 0.2 inch thick:— (18)

Specifications:—

Heat Treated (Test 4 days after treatment)

Yield point, tension (min.)	25,000 pounds per square inch
Ultimate strength (min.)	55,000 pounds per square inch
Elongation in 2 inches (min.)	17 per cent
Specific gravity	2.85 (max.)

Bend Test—In any direction must stand 180-degree bend over a diameter equal to four times the thickness of the sheet.

Annealed state (12 hours after treatment).

Ultimate tensile strength	25,000 to 38,000 pounds per square inch
Elongation in 2 inches (min.)	10 per cent

In sheet 0.2 inch thick or over, a safe minimum value of ultimate strength is 50,000 pounds per square inch, the other properties remaining about the same. For sheet of very light thickness, such as

Table III

Mechanical Properties of Sheet Duralumin Made by an American Producer

Condition	Heat treated (pounds per square inch)	Annealed (pounds per square inch)	Hard rolled (pounds per square inch)
Ult. tensile strength	55,000-62,000	25,000-35,000	67,000-72,000
Yield strength	30,000-36,000	.....	55,000-65,000
Elongation in 2 inches	18-25%	10-14%	3-8%
Brinell hardness	93-100	54-60	130-140
Scleroscope hardness	23-27	9-12	37-42

0.02 inch and under, a softer grade of material may be used, the tensile strength being 40,000 pounds per square inch or more, and the elongation about 15 per cent in 2 inches.

The properties of forgings follow those of sheet.

Like steel, the tensile properties of duralumin vary somewhat in transverse and longitudinal specimens taken from sheet. The longitudinal values (with the grain) are the more uniform, and show the higher ductility. Transverse tests show lower elongation and sometimes slightly higher tensile strength. This condition seems to depend largely on the practice used during manufacture; some sheets showing more nearly uniform transverse and longitudinal values than others.

The following are fair minimum values for tempered bar stock (hexagon, round, etc.) but may be improved upon:

Diameter	Tensile strength pounds per square inch	Elong. per cent in 2 inches
¼ to 1 inch	55,000	18
Over 1 to 1½ inches	50,000	18
Over 1½ inches	45,000	18

The dimensions of test speciments affect the results. Thin sheets give lower elongation values. Standard specimens must therefore, be agreed upon. Standard tensile specimens ½ inch in diameter with a 2-inch gage length, or of the same geometric proportions if of smaller diameter are used for bar stock. For sheet, 2-inch gage length ½ inch wide. is a tentative standard.

In general extruded duralumin is slightly lower in tensile strength than rolled or forged duralumin. Aside from this there seems to be little difference in properties.

Compression and Shear

The compressive strength of duralumin is about the same as the tensile strength. Following are the results of tests made on rolled and extruded rod, the specimens being 1 inch in diameter and 4 inches long. The extruded specimens were machined from a 2-inch diameter bar. The rolled bar was 1 inch in diameter. (4)

Compression Tests

Process	Condition	Yield point pounds per square inch	Ultimate strength pounds per square inch
Rolled	As rolled	36,000	51,000
Rolled	Tempered	25,000	56,800
Extruded	As extruded	22,000	48,000
Extruded	Tempered	25,000	58,000

Shear

Data scarce, but 27,000 to 30,000 pounds per square inch are accepted values for tempered material.

Wire

Tempered wire normally has:—

Tensile strength.....	60,000 to 65,000	pounds per square inch
Yield stress	30,000 to 35,000	pounds per square inch
Elongation in 2 inches.....	22 to 26	per cent

Cold drawn wire has been made with a tensile strength of 80,000 pounds per square inch. This is inferior in strength to piano or aviation wire of the same weight, but may have many practical uses.

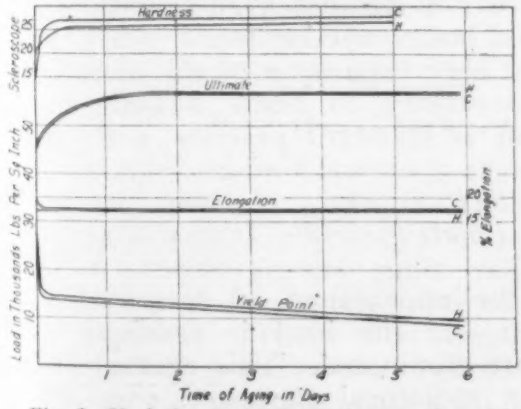


Fig. 5—Variation in mechanical properties with time after quenching in hot and cold water. $\frac{1}{16}$-inch duralumin sheet held 20 minutes in nitrate bath at 932 degrees Fahr.

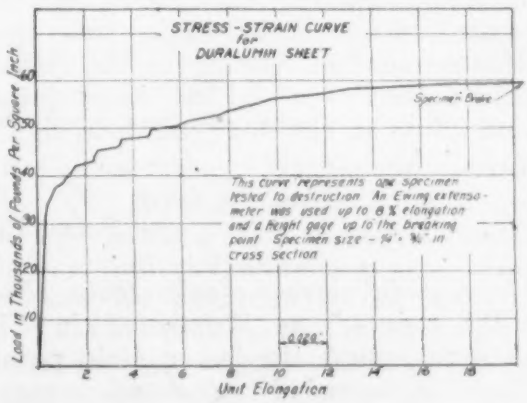

STRESS-STRAIN CURVE
for
DURALUMIN SHEET
Specimen Broke
This curve represents one specimen tested to destruction. An Ewing extensometer was used up to 6% elongation and a height gage up to the breaking point. Specimen size - ¼ x ¾" in cross section.
Load in Thousands of Pounds Per Square Inch
Unit Elongation

Fig. 6—Stress-strain curve for Duralumin Sheet. Specimen ¼ x ¾ inches cross-section.

Fatigue Endurance

Data on the fatigue endurance limits of duralumin are scarce. Endurance tests are underway at the Bureau of Standards and by vari-

ous manufacturers but results have not yet been published. The following is quoted from a German source:

"Duralumin when heat treated and cold worked to give about 6 per cent elongation in 2 inches corresponding to a yield point above 35,000 pounds per square inch, will withstand unlimited alternations of stress between 0 and 20,000 pounds per square inch tension." (13)

Experience, extending over a period of ten years or more in Europe has shown that the material is perfectly reliable when correctly used. Duralumin should not be used in thin sections where it will be subject to severe vibration while under stress, as at the joints of structural members in airplanes. At these locations it has been the German practice to re-enforce the joint with mild steel, attached to the duralumin members by rivets. Correct heat treatment and freedom from flaws and sharp reentrant angles are of course essential, as in all metals of construction. The following abstract from a paper by Rollason (23) is of particular interest:—

"The fatigue of the metal is indeed favorable. A sample connecting rod made for a standard passenger car was run in a special machine consisting of a motor-driven crank and weighted crosshead. The speed was about 1500 revolutions per minute and the load on the crosshead would correspond with about 50 per cent overload on the motor. The duralumin rod gave a life of 353 hours and was still functioning when a casting on the crosshead failed in fatigue. A standard drop-forged steel rod for the same car showed a life of only 25 hours under the same conditions, for example, with 50 per cent overload and another between 40 and 50 hours at normal load both the steel rods failing in fatigue at the big end. The steel rod was of smaller section, but about double the weight of the forged duralumin rod. Some of these rods also have stood up well in block and road tests in the motor to the extent of over 10,000 miles of running. A notable feature of a number of these tests has been that at the big end bearing, the rod has been run direct on the crankshaft without any bushing whatsoever. Forged and heat-treated duralumin, in fact, is showing up as a very satisfactory bearing material when the wear is against a sufficiently hard shaft. Rods have been run against both case-hardened and heat-treated shafts. Owing to the relatively high expansion of the aluminum alloys, however, it has been found necessary to allow a little more end play at the big end bearings than is standard practice with steel rods."

False Yield Points

Careful stress-strain tests show the appearance of several "false yield points," as illustrated in Fig. 6. If the load is removed and then reapplied, the lower yield points are eliminated. This characteristic may be regarded as an advantage for structural purposes, permitting the parts to adjust themselves to imperfectly distributed loads. These false yield points seem to be a peculiarity of the material in cold working. Both freshly quenched and aged specimens show this behavior. In testing freshly quenched specimens of sheet a distinct crackling sound was noted during pulling which seemed to be due to sudden yields occurring at various points, followed by hardening

at those points and transferring of the yield to some other point in the specimen. This action could be seen and felt.

Influence of Heat and Cold

Heat has an important influence on the strength (13) of duralumin. When heated, the strength decreases 10 per cent for an increase in temperature of 212 degrees Fahr. above room temperature and about 20 per cent for an increase of 300 degrees Fahr. The loss in strength increases with the increase in temperature. The elongation increases on first heating to a hardly appreciable extent, while between 300 and 390 degrees Fahr. it decreases. At 480 degrees Fahr. the elongation becomes the same as at room temperature. With further heating the elongation increases with increase of temperature.

A graph by Cohn (12) showing the influence of heat on the tensile properties of duralumin is reproduced in Fig. 7. As opposed to the influence of heat on the mechanical properties of duralumin, its strength

Table IV
Influence of Cold on the Strength of Duralumin

Testing temperature	The bar was tested in	Tensile Tests: Limit stretch and strain	Tensile Tests: Ult. strength kg/mm²	Tensile Tests: Elongation %	Impact test work of breaking kg/mm²
+ 20° C	Air	24.0	42.5	21.9	2.6
0	Snow	23.6	43.0	21.8	2.6
— 20	Mixture of snow and table salt	24.0	43.7	23.1	2.7
— 40	Mixture of snow and calcium chloride	24.0	44.0	22.1	2.7
— 80	CO_2 snow	25.2	44.4	22.7	2.7
—190	Liquid air	32.3	53.7	28.7	2.6
+ 20	Air	23.0	42.3	23.3	2.6

and elongation are somewhat increased by a decrease in temperature, the impact strength being practically unaffected. The results of some German tests at temperatures down to that of liquid air (310 degrees Fahr.) below zero are given in Table IV. (13).

Properties Compared with Steel and Aluminum

A comparison between some of the properties of duralumin, aluminum and steel is given in Table V. The strength weight factor or "strength-weight efficiency," obtained by dividing the tensile strength by the specific gravity (unit weight) of a material affords a very clear comparison between the value of materials for purposes where strength and lightness are of first importance. On this basis, duralumin is 17 per cent better than a good alloy steel, and nearly three times as good as mild steel or half hard aluminum, while its ductility is higher than that of the alloy steel, nearly as high as the mild steel, and nearly twice that of half hard aluminum. Its weight is only about 6 per cent greater than that of aluminum, but its strength is 3.0 times that of half-hard aluminum and 4.5 times that of soft aluminum. (12,000 pounds per square inch). Its unit weight is about 36 per cent that of steel, or roughly 1/3. The modulus of elasticity of duralumin is

practically the same as that of aluminum and about 1/3 that of steel. This, in relation to the area for a given strength makes duralumin about equivalent to steel as a long column or beam where failure occurs by flexure.

For light sections, duralumin has a great advantage over alloy steel as it is less subject to local or detail failure, being approximately three times as thick for the same strength and weight. Alloy steel sections of equal strength (theoretical) and weight, as those of thin duralumin, would fail by crinkling, and would be too thin to be practicable. The ease with which duralumin can be machined, forged, drawn, etc,. gives it a great advantage over its structural competitor, alloy steel, and offsets some of the difference in first cost, which is at present roughly 4 or 5 times that of alloy steel per pound. This is largely offset by the fact that about three times as much material is obtained as for an equal weight of steel.

Fabrication

Drawing, Forming, Etc.

The peculiar "ageing" property of duralumin, namely, its softness immediately after quenching, followed by gradual hardening and increase of strength at room temperature, is in some ways an advantage

Table V
Comparison of Properties—Duralumin-Aluminum-Steel

	Duralumin tempered	Aluminum half hard	Mild steel	Alloy steel
Specific gravity	2.85	2.7	7.8	7.8
Weight, lb./cu. in.	0.101	0.094	0.27	0.27
Wt. 1 sq. ft. 0.1″ thick in pounds	1.44	1.35	3.90	3.90
Tensile strength, pounds per square inch	55,000	18,000	55,000	125,000
Yield point, pounds per square inch	25,000	.....	36,000	100,000
Elongation in 2 inches	17%	7%	20%	15%
Modulus of elasticity (millions)	9.4 to 10	9.8	30.	30.
Strength/weight factor, S/W	19,250	6,650	7,050	16,000
S/W compared, duralumin 100%	100	33.5	36.6	83
Section area for equal weight	1.00	1.05	0.36	0.36

in fabrication, as it permits severely working the metal just after heat treatment. Such work should be done within the first hour after quenching. Quenching in cold water gives greater softness and a longer period of working than in hot. Rivets are heat treated just before use. They are headed easily and then attain their full strength without further attention. Long channels and other sections may be produced by heat treating a coil of flat strip, then straightening and rolling it to shape immediately. The long straight members would be difficult to handle in heating and quenching if annealed material were used and heat treated after forming. Either heat treating or annealing may be repeated a number of times without ill effects. (Specimens of duralumin wire have been heat treated successively 20 times without appreciable change in physical properties.)

In general, if only *one* operation is required to finish a part, it may be quenched (heat treated) just before that operation. If several operations are required, annealing is preferable, tempering treatment being

given just before, or after the last operation. It is advisable in shops where duralumin is used in large quantities that all stock duralumin which is in the annealed condition shall be painted a distinguishing color. (Blue has been adopted in British practice.) Annealed or freshly quenched sheet duralumin may be formed and deep drawn to a considerable degree through somewhat less than soft aluminum. In bending soft material, a *minimum radius* is the thickness of the sheet, and for tempered material, twice the thickness. Annealed material must be finally heat treated to attain maximum tensile properties. Light sections and sheet in either the hard or soft state are conveniently cut on a metal cutting band saw.

Extrusion

Extrusion of light, as well as of heavy sections is practicable. Some tubes intended for use in the honeycomb type of radiator were

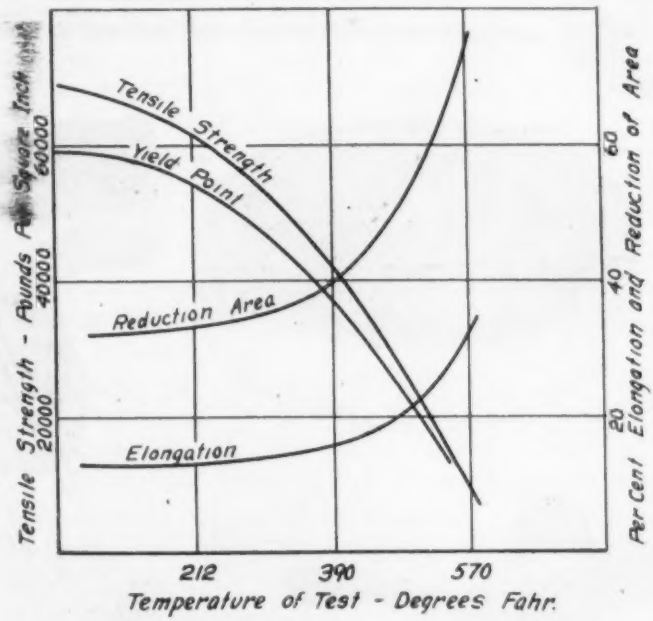


Fig. 7—Effect of Heat on Tensile properties. (After Cohn. Ref. 12.)

recently produced by an American manufacturer. These were 5 inches long, with an outside diameter of 0.26 inches and a wall thickness of 0.009 inches. The ends were expanded to a hexagonal shape for about ¼ inch.

Machining

The metal can be turned and machined at the same speed as brass and it does not seize or drag the tools like some aluminum alloys. It machines best in the tempered or hard rolled state. Kerosene has been found a good tool lubricant in machining and may be run smoking hot. British references (6) recommended paraffin oil, in threading and finishing. The metal threads well in the hardened state; but threaded parts are preferably used in conjunction with a different metal (brass

or steel) on account of the tendency of duralumin to seize or bind when in rubbing contact with itself.

Soldering

Duralumin may be soldered by the same means as aluminum, but the heat of soldering would tend to anneal heat treated material, and if heat treatment were done after soldering, the solder would be melted. In any case soldering is not recommended, as all known solders for aluminum rapidly deteriorate in the presence of moisture, so that the strength of the joint is completely lost. The action is due to electrolytic corrosion. (11) In soldering metal parts which are to come in contact with duralumin, great care should be taken to completely

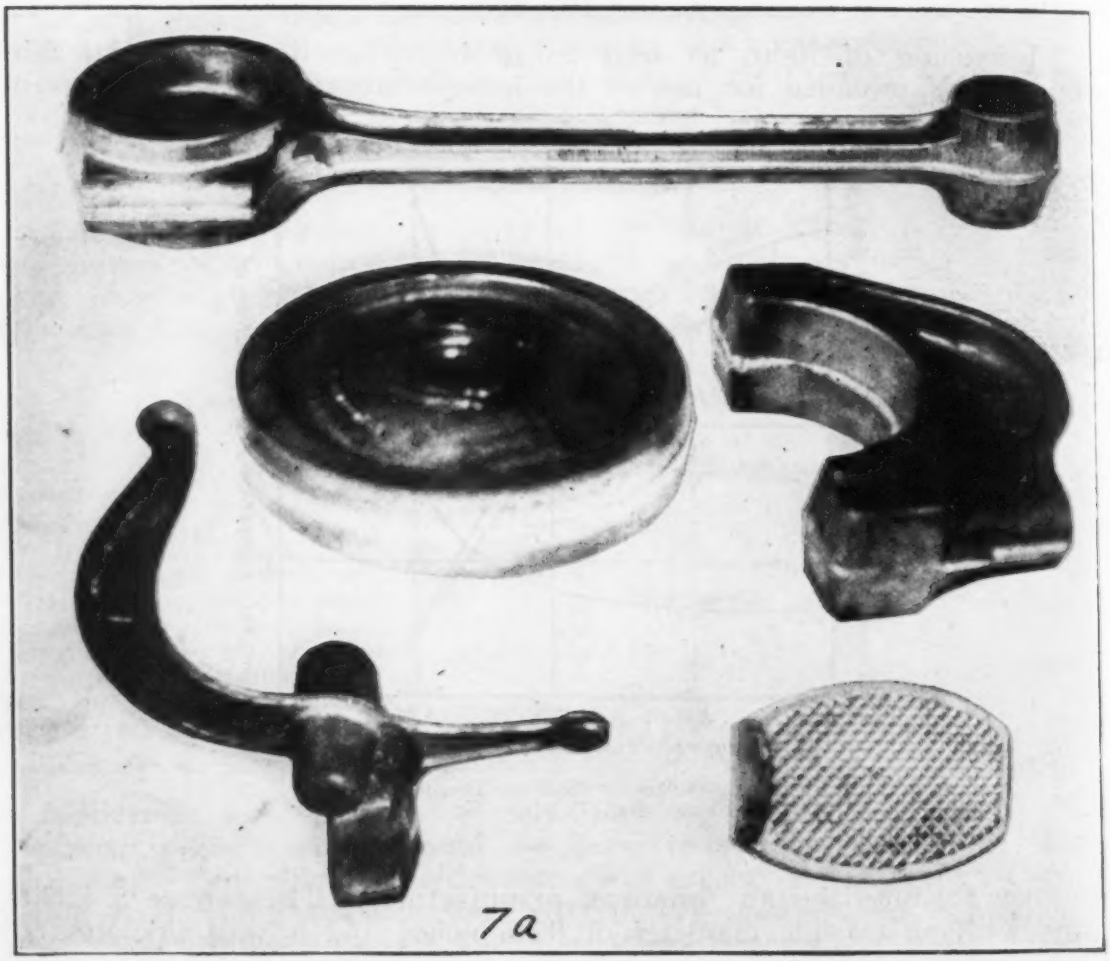


Fig. 7a—Small forgings manufactured from aluminum alloy. (Courtesy Aluminum Company of America.)

remove all traces of soldering flux containing corrosive materials, such as zinc chloride, etc., or better, to use a non-corrosive flux, such as resin, stearic acid, etc.

Welding

The welding of duralumin has heretofore been considered impracticable. Recent experiments. (19) have shown that it may be welded in about the same manner as aluminum, except that more care and skill are required on account of greater tendency to melt, become

brittle or "burn," and buckle. Narrow strips sheared from the sheet were used for welding rod. Strong welds may be made by either the "butt" or the "flange" method. The flange method is preferable, as it produces a fillet on the under side of the weld, whereas the butt method is apt to leave a sharp reentrant angle there, which would tend to cause failure under vibration. Flange welds are easier to make than butt welds on thin sheets.

In making the butt type of weld the sheets to be joined are placed edge to edge and "tacked" together at intervals of about one inch by melting the edges together at those points and adding a little metal from the welding rod. Fresh flux is then applied and the weld made continuously by melting the edges together and building up the joint with metal from the welding rod. This type of weld is more successful with sheets of 16 BWG (0.065 inch) thickness, or thicker, than with lighter gage sheets, as the latter melt through very easily. In making the flange type of weld, the edges of the sheet to be joined are bent up at right angles, an amount equal to about three times the thickness of the sheet. These flanged edges are clamped together (conveniently done with small "C" clamps) and tack-welded at intervals of 1 inch or less. (19) Flux is reapplied to the joint after tacking and the weld is then completed by melting down the flanges and adding a little material from the welding rod where necessary, although as a rule little or no additional metal is needed. This method of welding leaves a good fillet on the lower as well as the upper surface of the joint and is for some purposes, more satisfactory than plain butt welding. Where the bends in flanging run parallel to the grain it is advisable to anneal the sheet before bending by heating to 600 to 750 degrees Fahr., to avoid cracking.

The behavior of the metal in making either butt or flange welds is similar to that of aluminum in that it is necessary to progress continuously at an even speed along the weld. It is difficult to make a new start in a weld which has been allowed to cool or which has burned through. A very small oxyacetylene torch is employed. The same fluxes used in welding aluminum have been found satisfactory for duralumin.

All traces of welding flux must be removed to avoid corrosion. This may be done by completely submerging the part in a 10 per cent solution of sulphuric acid in a non-metallic container, for one hour, followed by through rinsing in running water. Exposure to the air while in the acid will cause local pitting.

Tensile tests on welded joints, heat treated but not dressed, varied from about 50 to 100 per cent of the strength of the sheet, and on dressed joints, heat treated, varied from about 25 to 80 per cent by either method. Heat treatment should follow welding. Without heat treatment there is rapid corrosion along a line parallel to and about an inch away from the welded joint in the presence of moisture, especially salt water spray; see Fig. 8. The weld itself is not attacked. This effect is apparently electrolytic, due to a physical difference between the metal exposed to the heat of welding and the remaining metal. Heat treatment of the whole part after welding eliminates this condition. Heat treatment also greatly increases the strength of welds. Heat treatment may be by either oil or water quenching. Air-cooling has been

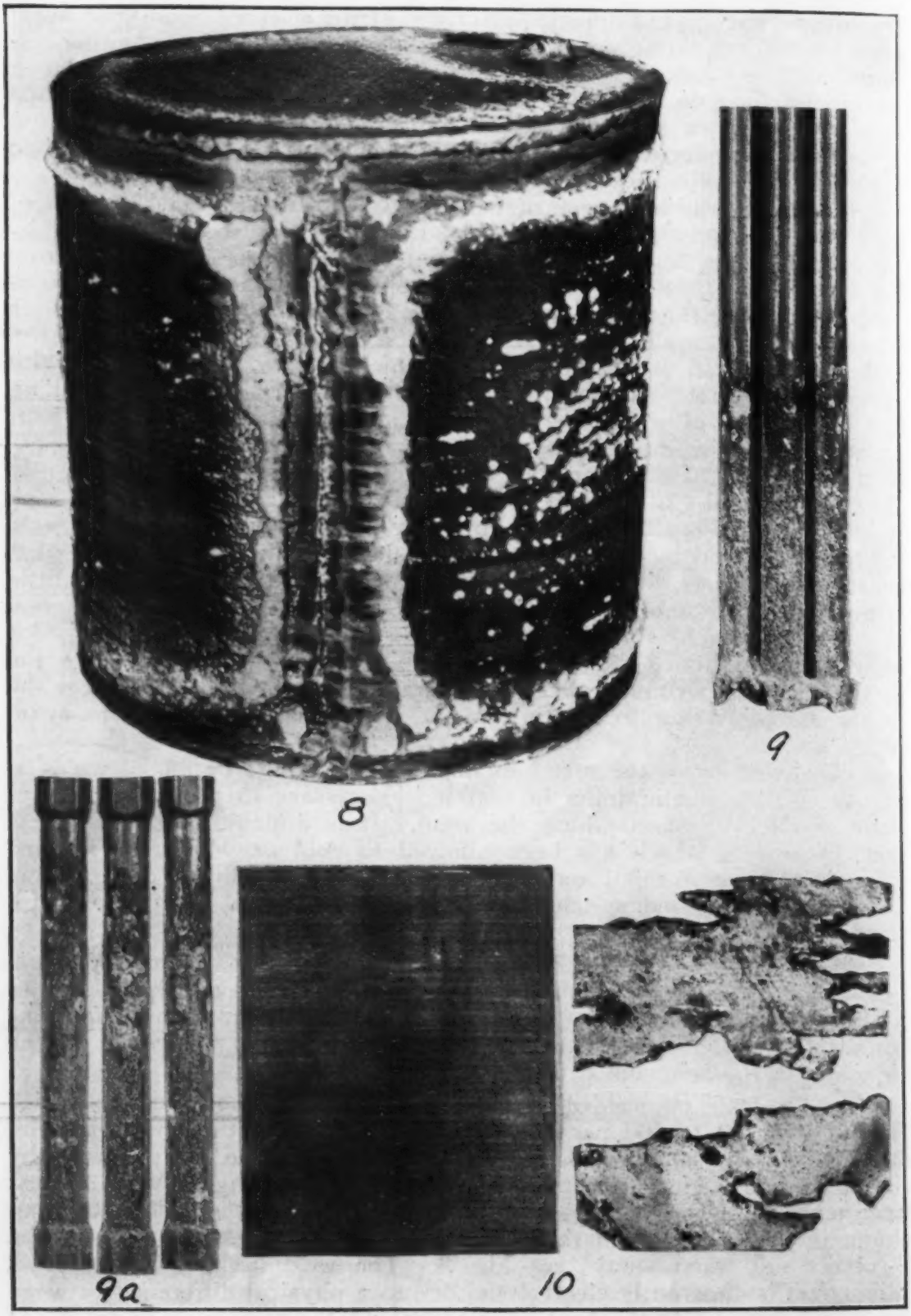


Fig. 8—Corrosion of unheat treated welded duralumin after 5 days in salt water spray test. Figs. 9 and 9a—Heat treated duralumin tubes, perforated after 2 months immersion in tap water. (Dia. ¼ inch, thickness 0.01 inch). Fig. 10—Heat treated duralumin sheet 0.01 inch thick before and after 6 months exposure to salt water spray test.

tried with some success. The greater convenience of air quenching large articles might warrant its use in some cases even at some sacrifice in strength.

Beads, grooves, dished heads, or crowns around welds are often necessary to take care of the high thermal expansion during welding.

Duralumin may be welded to aluminum sheet, and even to copper-aluminum alloy castings, but this tends to induce electrolytic corrosion in the presence of moisture. Plain aluminum welding rod was used with success, but gives a weaker joint, and is subject to corrosion.

Corrosion

The statement that duralumin is not corroded by fresh or salt water should be taken with caution. Heat treated sheet and thin tubes have been perforated after two months immersion in tap water; visible attack setting in within one to two weeks, as shown in Fig. 9. Experiments (20) have shown heat treated duralumin sheet to be rendered entirely worthless after a few months exposure in the salt water spray tests; see Fig. 10. Corrosion in fresh or salt water is manifested by the appearance of a white gelatinous precipitate (aluminum hydroxide?) at localized points on the specimen. This is accompanied by a darkening of the surface. Continued exposure results in blistering, scaling, pitting, perforation and eating away of the sheet, and often by splitting apart at the edges, due to destruction of the interior material. When dried, the precipitate turns to a white powder, apparently aluminum oxide. Immersion in 10 per cent nitric acid removes the products of corrosion without noticeably affecting the metal and facilitates inspection of test specimens. It has been shown (27) that duralumin sheet when exposed to some reagents is subject to a type of corrosion which is truly intercrystalline in character, resulting in brittleness. Comparative tests (20) made on duralumin and commercial aluminum sheet (98 per cent pure) in exposure to salt spray and in immersion in tap water gave distinctly superior results for the aluminum.

Effect of Heat Treatment

Heat treated metal which has been annealed at certain areas, as by welding, is severely attacked at the juncture of the annealed and tempered material, as shown in Fig. 8. Reheat treating the entire part prevents this locallized action. Heat treated duralumin is more resistant to corrosion than the annealed material. The rate of cooling in heat treatment has a strong influence on its resistance to corrosion, as indicated by the salt spray test. This influence is proportionally greater than the influence on the tensile properties. The degree of corrosion, as indicated by the appearance of test specimens taken from the same sheet, heat treated by quenching from 932 degrees Fahr. in various mediums, aged for 10 days, and exposed for 30 days in the salt spray test, may be graded as follows:

	Quenching medium	Degree of corrosion
(a)	Water at 60 degrees Fahr	Very slight
(b)	Water boiling	Slight, but more than (a)
(c)	Quenching oil, at 70 degrees Fahr	Same as (b)
(d)	Air, fan blast 65 degrees Fahr	Severe, scaled
(e)	Still air, 65 degrees Fahr	Very severe. Deeply scaled

Specimens are shown in Fig. 12.

The physical properties of these specimens after heat treatment are discussed under *quenching mediums,* and given in Table I.

Permanence of Polish

Polished duralumin will apparently remain bright indefinitely when not exposed to moisture, and is not stained by handling.

Effect of Gasolene

Neither gasolene nor benzol, although containing considerable quantities of sulphur in solution, have any appreciable corrosive effect on duralumin, heat treated or otherwise.

Salt Spray Test

The salt spray test is a much accelerated test; that is it is much more severe than ordinary atmospheric exposure, even on the sea. In the test, the specimens are suspended in a nonmetallic box with a glass cover, and kept constantly moist with a solution of common salt

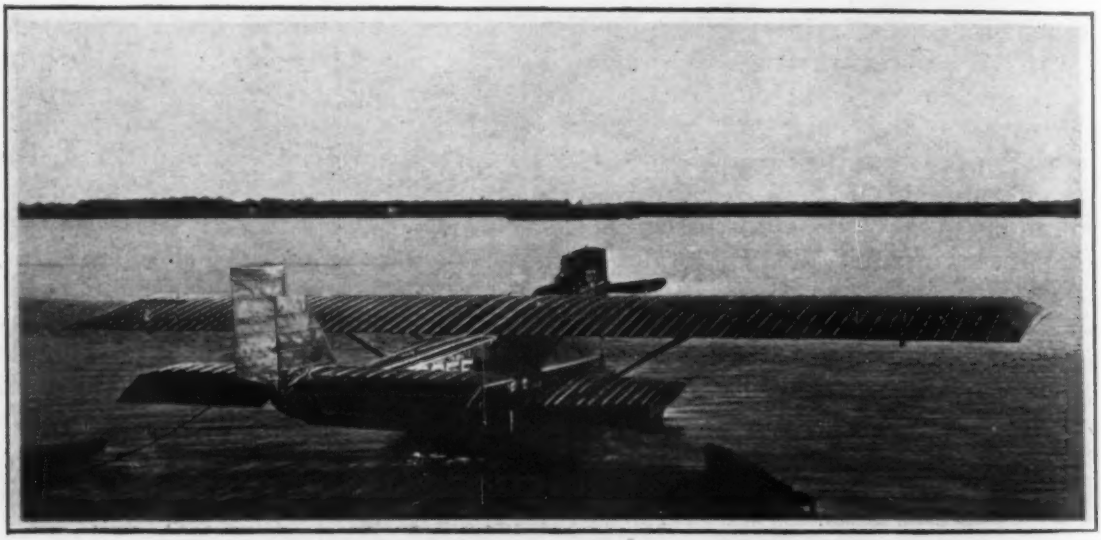


Fig. 11—All-Duralumin Seaplane, Dornier, CS-2.

in water, (20 per cent by weight) atomized by means of a compressed air jet. Galvanized steel fittings, intended for use on seaplanes, are required to withstand this test for 100 hours, (4 days), without signs of rust.

Causes of Corrosion

The corrosion of unprotected duralumin in the presence of an electrolyte seems to be a question of time. The action is apparently electrolytic, due to local differences of compositions or of heat treatment in the metal. The segregation of impurities, or of normal constituents of the material is probably responsible for pitting and splitting. The purity and uniformity of the material is no doubt, an important factor. Corrosion doubtless is accelerated by the proximity of metals electronegative to duralumin in the presence of an electrolyte. Corrosion has been ascribed to mechanical strains set-up by working aged material. In tests made by the writer, it has never been found that severely bent or cold worked portions of specimens corroded more than unworked

portions. For example, tensile specimens placed in the salt spray test after fracture showed no more severe corrosion at the gaged length than at the butt ends.

Exposure Tests

Some very favorable corrosion tests of duralumin are quoted from foreign sources, as follows:—

U—profiles of duralumin, copper, iron, aluminum alloys, pure aluminum and Electron metal were exposed to the action of sea air on a light ship in the North Sea for three months. These sections were also riveted and screwed together. Duralumin resisted these conditions better than any of the other materials, and showed practically no oxidation. (12).

Tests made at the shipbuilding docks at Vickers, Ltd., in England, by hanging four pieces one foot square so that they were immersed at high tide, but above water at low tide, showed a loss in weight after six months of approximately 0.001 gram per square centimeter. Specimens exposed in the open air alongside a dock for eight years were only slightly discolored and showed the same strength as obtained a week after heat treatment. (6).

Exposure tests made on the roof of a building at the Durener-Metallwerks, Germany, on bars and wires, for a period of 2½ years, showed no evidence of any alteration in hardness or ductility. (13).

Chemical Reagents

The effect of 14 months immersion in hydrochloric, nitric, sulphuric and acetic acids of various concentrations as well as other reagents, has been studied (12). In general, the action of acids is slow.

Like aluminum, duralumin is rapidly attacked by alkalies.

Electrolysis

Metals electrolytically negative to duralumin are copper, brass, bronze, iron, steel, etc. These metals should presumably not be joined to duralumin where subject to moisture. However, the following is quoted from a German source: (13).

"Experiments made on the electrolytic effect from junctions of duralumin with iron or steel show that only insignificant destruction of the iron at such riveted joints takes place in artificial sea water." (13).

Under ordinary atmospheric conditions, when protected from the weather, there would probably be no serious damage resulting from such joints.

Protective Coatings

Spar varnish is a good protective coating for duralumin. The varnish may be tinted by the addition of about 4 per cent of American Blue ground in oil. This makes it easier to see that parts have been properly coated, and is sufficiently transparent to permit inspection for surface defects in the material. Enamel or paint may be applied over the varnish. The direct application of coatings having zinc or lead pigments is not recommended. Powdered aluminum mixed with bronzing liquid, has proved a satisfactory coating on duralumin airplane wings, and certain commercial paints and lacquers have given promising results under test.

Uses

Aircraft

Duralumin is still practically the only suitable material of construction for rigid dirigibles (airships of the Zeppelin type) for which purpose it was originally developed. In these, the frame work is of latticed girder construction consisting of transverse frames spaced by longitudinals. The girders are, as a rule, of triangular section, each corner consisting of a U-shaped channel; these are crossbraced with stamped lattices. The lattices are stamped from strips and are of highly efficient design. Girder joints are made by riveting and are sometimes quite intricate.

After having demonstrated its reliability as a material of constructures for dirigibles; duralumin was employed in Europe in the con-

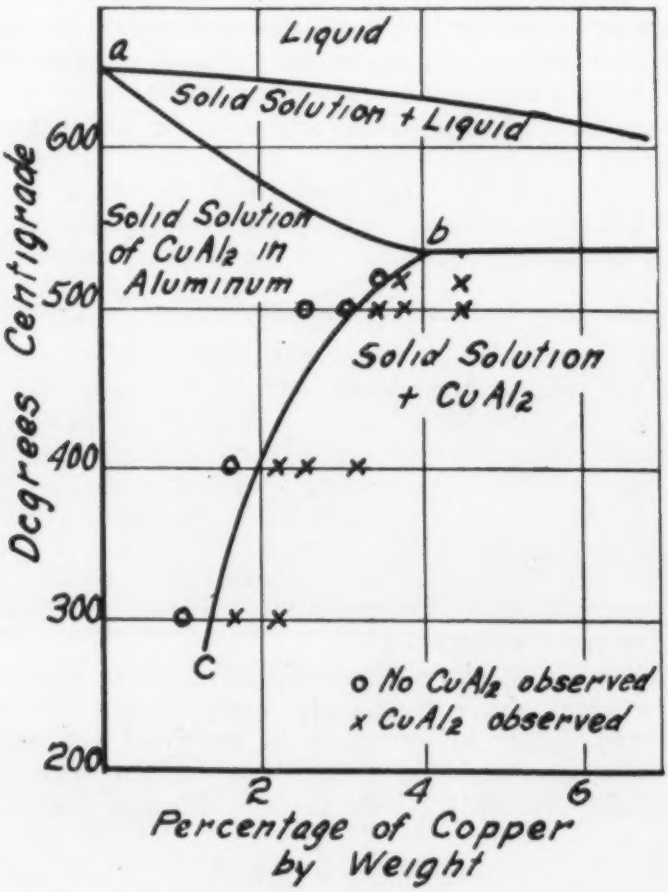


Fig. 12—Partial equilibrium diagram of Copper-Aluminum series showing solubility curve of Cu Al_2 in aluminum. (After Merica.)

struction of airplanes. One of the earliest and most successful of these was the Junker all-metal monoplane. Several successful types of all metal duralumin planes have been developed abroad and new models are being built in this country. In airplane construction, it is necessary that the machine be specially designed to obtain the full structural value of the material. This generally includes using sheet duralumin as a wing covering, where it acts both as a structural mem-

ber and as a wing surface, replacing the usual fabric. Besides lightness and rigidity, it has the advantage over wood and fabric of being non-inflammable. Duralumin is also used in spars, struts, ribs, etc., with a fabric covering. An all duralumin seaplane is shown in Fig. 11.

Automotive

The use of duralumin is rapidly spreading to other industries, where strength and lightness are important, notably the automobile. Worm wheels and gears and helical spur gears of duralumin have given good results when run against hardened steel. Pressures should be well within 30,000 pounds per square inch. Quiet running is claimed. This is probably due to the difference in pitch of the sound vibrations in the two metals.

Duralumin connecting rods running directly on the wrist pins had longer life at this point than with the conventional bronze bushed rod of equal bearing area. Tests of duralumin used as a bearing metal against babbitt, show that for shaft speeds over 700 revolutions per minute and loads over 200 pounds per square inch, duralumin bearings develop less friction, remain cooler and show practically no loss in weight under most severe conditions. (15)

General

The many valuable properties of duralumin open an almost unlimited field of usefulness, for example: Reciprocating parts for engines and machinery, gears, automobile parts, wheels, and bodies, handles, miscellaneous hardware, lawn mowers, surgical and dental accessories, scientific, electrical and musical instruments, telephone and radio apparatus, office equipment, metal patterns, forged, pressed and stamped shapes of great variety. Its bell-like tone suggests a possible use for chimes and gongs. The duralumin alloys in various forms are now obtainable from at least three competent manufacturers in this country, and from foreign sources.

Constitution
Metallography and Theory of Heat Treatment

Hardening and Ageing

The writer will endeavor to briefly recapitulate the theory of heat treatment of duralumin as presented in articles by Merica (1) (8) Jeffries (7) (28) and their associates.

In spite of an apparent difference in behavior, there is a marked analogy between the heat treatment phenomena of duralumin and steel. The hardening of duralumin in heat treatment depends primarily on the presence of small amounts of copper. Copper forms a compound, $CuAl_2$, with aluminum. (Compare the compound Fe_3C, between carbon and iron, in steel). This $CuAl_2$ forms an eutectic with aluminum which is relatively hard and brittle. (Compare pearlite in steel). This eutectic contains about 32 per cent copper by weight and melts at 1005 degrees Fahr. It is found in the various casting alloys of copper and aluminum. (Notably "No. 12", Cu. 8 per cent Al 92 per cent. These become harder and more brittle as the copper content ($CuAl_2$) increases.) (Compare hard and brittle high carbon steel).

$CuAl_2$ is soluble in solid aluminum in small amounts increasing from

about 1 per cent copper by weight at room temperature up to a maximum corresponding to about 4 per cent of copper by weight, at 1005 degrees Fahr. (above which the $CuAl_2$ melts). This is clearly shown in the partial equilibrium diagram, Fig. 12, by Merica (1).

Therefore, if a copper-aluminum alloy containing about 4 per cent Cu by weight be heated to nearly 1005 degrees Fahr. the $CuAl_2$ will go into solid solution (possibly as Cu in aluminum) (Compare solid solution of carbon or carbide in steel). The amount of $CuAl_2$ in solution will depend upon the temperature. The hardness and tensile strength of duralumin increase with the temperature to which it is heated before quenching up to 1005 degrees Fahr. and then decrease rapidly, see Fig. 1. That is, these properties depend upon the amount of $CuAl_2$ which is in solution at the moment of quenching. Heating above 1005 degrees Fahr. melts the $CuAl_2$ and damages the material. When the saturated solution of $CuAl_2$ in aluminum is quickly cooled, as by quenching, the

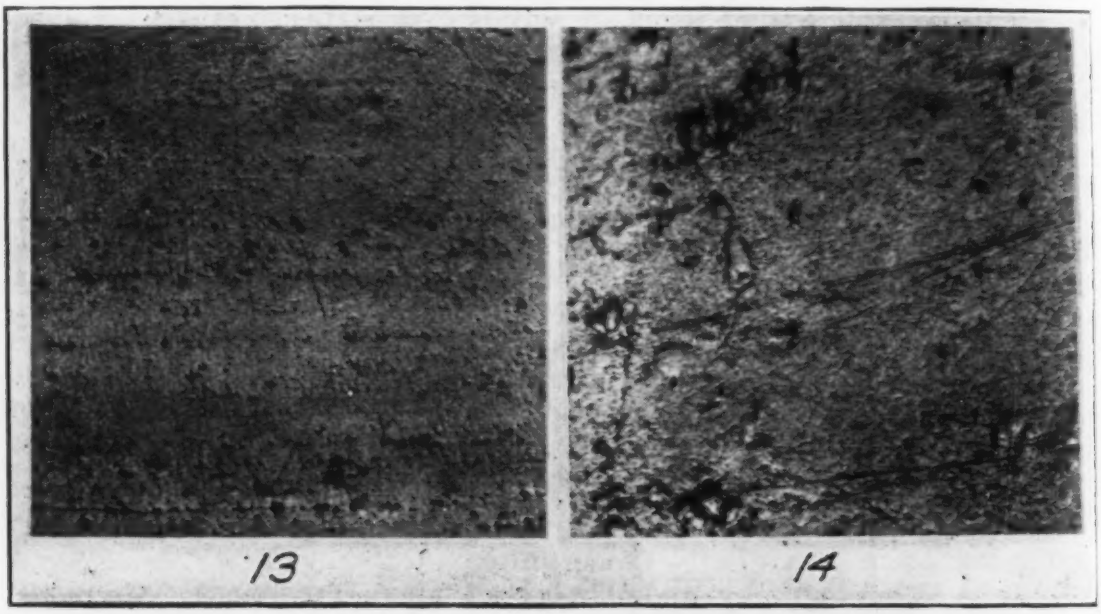


Fig. 13—Heat treated Duralumin sheet. X 100. Longitudinal section polished, not etched. Dark particles probably undissolved or excess Cu Al_2 and impurities. Fig. 14—Same as Fig. 13 magnified 500 times.

$CuAl_2$ is held in solid solution in a state of unstable equilibrium, (or is precipitated in extremely small, perhaps molecular, particles, not visible under the microscope).

(Jeffries (7) points out that the smallest globule of $CuAl_2$ resolvable under the microscope contains about two billion (2,000,000) molecules). If the cooling is slow, as in the furnace, the $CuAl_2$ will be precipitated in relatively large particles, perhaps large enough to be seen under the microscope. When the rate of cooling has been very slow, no change in physical properties takes place on ageing. After rapid cooling, (quenching,) the hardness and strength of the metal increases at ordinary temperatures, reaching a maximum in about 10 days, after which they remain permanent. This is called "ageing." See Fig. 4.

If this alloy is quickly cooled and then kept at the temperature of liquid air, no ageing takes place. If it is then raised to ordinary room temperature, ageing proceeds. In a climate as cold as liquid air we

would have to heat duralumin after quenching to produce any change in properties. Ageing, even at normal room temperature must, therefore, be considered a form of *heat* treatment.

Hardening Due to Precipitation of $CuAl_2$

Pure aluminum unlike ferrite, undergoes no known allotropic changes between room temperature and its melting point. But if duralumin is reheated immediately after quenching, an evolution of heat occurs at about 480-530° F. (250-275° C.) (1) This is not an allotropic change, and is not reversible on cooling. Merica (8) has shown that this heat effect is due to the precipitation of $CuAl_2$, which was held in solid solution by quenching. When duralumin is kept at a very low

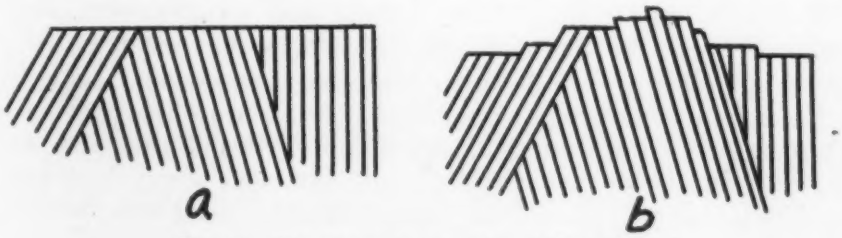


Fig 15—Slip planes in crystals. (After Desch.)

temperature (as in liquid air) after quenching, the $CuAl_2$ is held in unstable equilibrium. If allowed to remain at room temperature, or if heated to 212 to 305 degrees Fahr. the precipitation takes place slowly and gradually and we have the phenomenon of ageing. The same evolution of heat doubtless takes place during such ageing but is too slow to be noticeable. (If the quenched duralumin has aged to maximum hardness, or if it has been annealed, no evolution takes place on heating to 480 to 530 degrees Fahr.)

When aged at ordinary temperature, or even at 212 or 305 degrees Fahr. the precipitated particles are too small to be seen under the microscope. No difference can therefore be detected optically between the microstructure of aged and freshly quenched specimens. (8) Some particles of $CuAl_2$ are generally visible after heat treatment, under ordinary magnifications, perhaps due to imperfect solution or excess copper; see Figs. 13 and 14.

The hardening of duralumin is therefore due to the precipitation of minute particles of $CuAl_2$ from solid solution, temporarily held in unstable equilibrium by sudden cooling. (8) However, if duralumin is quenched and then aged at a temperature of about 395 degrees Fahr. the hardness increases rapidly to a maximum and then *decreases* (1). If the ageing temperature is still further raised, softer material results. Upon heating to the *quenching* temperature and cooling very slowly, particles large enough to be visible under the microscope are formed, and the material is very soft, much softer than even freshly quenched material, having a scleroscope hardness of 7 to 10 as compared to 16 for the latter. Duralumin so annealed hardens little or none upon ageing. Ageing therefore consists in the formation of fine nuclei of $CuAl_2$ which coalesce into larger particles at ordinary temperature and into still larger particles at higher temperatures (above 395 degrees Fahr.)

Critical Dispersion

Immediately after quenching the precipitated particles of $CuAl_2$ are

very fine and the material is soft. Upon normal ageing the particles become larger and the material reaches maximum hardness. At higher temperatures the particles increase further in size, but the hardness decreases. In general, the tensile strength follows the hardness. It is therefore, evident that the maximum hardness and strength of duralumin depends upon the formation of particles of $CuAl_2$ of a particular average size, intermediate between the extremely fine ones produced after quenching and the coarser ones produced by heating above 395 degrees Fahr. The size of particles for maximum hardness may be called the "critical" size, or according to Jeffries (7), the condition of "critical dispersion." The growth of these particles depends upon molecular migration, which depends upon both time and temperature, but primarily upon temperature. At ordinary temperatures hardness attains a maximum in about 10 days and then remains permanent. At 212 to 305 degrees Fahr. the maximum is reached more quickly and is somewhat higher, but is also permanent. At 395 degrees Fahr. the critical size and maximum hardness are reached quickly, but growth continues with consequent softening. Therefore, temperature, not time, is the determining factor.

Ship Interference Theory

Jeffries and Archer (28) have offered a very reasonable and interesting explanation for the hardening effect of these particles of "critical size." They first define hardness as "resistance to permanent deformation" and state that metals owe their hardness and strength primarily to the attracting forces between their atoms. The full effect of this atomic cohesion is never realized, for "rupture always takes place by degrees and the breaking of atomic bonds is not simultaneous." The regular arrangement of the atoms in the crystals of metals gives rise to planes having a low resistance to shearing stress, called "slip" planes. (It is easier to slide the atoms past each other than to pull them apart.) The deformation or failure of metals usually occurs along "slip" planes in the crystals, as illustrated diagrammatically in Fig. 15, after Desch, and their appearance in ferrous and other metals after straining is well known. Anything which will interfere with this slip tends to increase the hardness and strength of the metal.

Quoting Jeffries and Archer further:—"The hardening and strengthening of metals by any of the known methods may be considered as due principally to interference with slip.... In duralumin we are dealing with an aggregate composed of a relatively weak matrix—aluminum,—greatly strengthened by the presence of small, hard, *diconnected* particles of $CuAl_2$." In explaining the manner in which this strengthening is accomplished, the authors compare a crystal of metal, with its parallel planes of easy slip, to a stack of iron plates placed in a strong magnetic field which acts at right angles to their surfaces, as illustrated in Fig. 16. ("This stack of plates presents a rather close analogy to the conditions obtaining in a ductile crystal, especially in that the forces which hold the atoms of a crystal together are probably electromagnetic in character.") The plates would slide over each other much more easily than they would pull apart. The force required to overcome such sliding or slip is analogous to that required to produce deformation (or rupture) in a ductile metal. Fig. 17 shows how these plates

might be "keyed" together, by the presence of many small hard spherical particles, so that slip would be greatly resisted. A similar condition exists in duralumin when the particles of $CuAl_2$ have coalesced to the critical size. If a number of the key particles were united into a single large particle, as shown in Fig. 18, there would be many planes of slip left unkeyed, and resistance to deformation would be decreased. This explains the softening of duralumin produced by ageing at higher temperatures (395 degrees Fahr. and up) or by annealing. The key particles have massed into larger particles which are relatively far apart, leaving the intervening spaces free to slip.

The strengthening effect of the hard particles evidently increases with their number, and not with their size. However, when the particles are very small, as just after quenching and therefore most numerous, the material is soft. The rule that hardness increases with the *number*

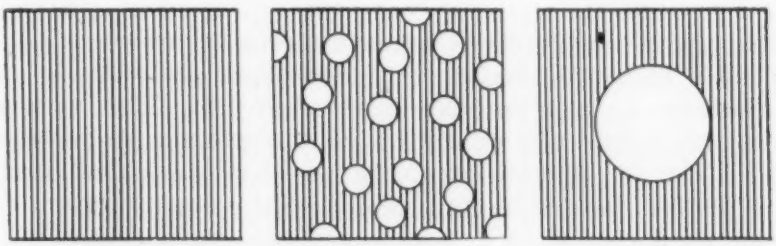


Fig. 16 Fig. 17 Fig. 18

Fig. 16—Set of planes of easy slip in a crystal having no internal slip interference. Fig. 17—Slip planes "keyed" by hard particles. Fig. 18—Reduced slip interference. Hard constituent gathered into a single large particle, leaving many planes without reinforcement. (After Jefferies and Archer.)

of particles therefore "must reach a limit as the particles approach atomic dimensions. . . . . The key formed by the little group of aluminum atoms surrounding the copper atoms in the solid solution is more easily sheared through than is a particle of crystalline $CuAl_2$. The critical dispersion for maximum hardness should, therefore, consist of the smallest possible particles having the characteristic crystallinity of the compound." (28). In other words the atoms in solid solution exert a hardening effect (freshly quenched duralumin is harder than pure aluminum) but they are not as good keys as are small bodies of $CuAl_2$. There is probably a limiting size below which $CuAl_2$ particles do not have the characteristic hardness and strength of the material. When the particles are too small they are not strong keys; when they are too large they are stronger but too far apart, leaving unkeyed areas. The intermediate or critical size therefore gives the most effectual resistance to slip and consequently the greatest hardness and strength.

The writer has endeavored, above, to outline the critical size theory, as presented in papers by Merica, (1) (8), Jeffries (7) (28) and their associates. It seems that the explanation of hardening might be simplified by considering that the $CuAl_2$ is held in solid solution in quenching, remains so at very low temperatures, as in liquid air, and is precipitated slowly at ordinary temperatures, and more rapidly up to 395 degrees Fahr. while at 480 to 530 degrees Fahr. all is suddenly precipitated with evolution of heat, as shown by Merica. If $CuAl_2$ goes into solid solution as atoms of Cu in Al on heating, and is so held upon quenching, the hardening effect upon ageing may be simply due to the *precipitation* of the most minute possible particles of $CuAl_2$, hardness increasing as more of the $CuAl_2$ is precipitated

until all is precipitated except that normally soluble at room temperature. Higher temperature, by causing coalescence of the precipitated $CuAl_2$ into larger particles, would cause softening by reducing the *number* of "keys," as explained by Jeffries. The maximum quantity of precipitated $CuAl_2$ dispersed in the smallest possible particles (molecules?) would have the maximum hardening effect. On this basis it would apparently not be necessary to explain the "critical size" phenomenon as done by Jeffries and Merica.

Continuing with the effect of slip interference on tensile properties: Ductility depends upon the amount of deformation (slip) which can be produced in a material before rupture. If the resistance to slip becomes as great as the direct rupturing strength (pulling apart) of the atomic bonds, brittleness, with relative hardness, results. Aged duralumin is therefore less *plastic* than when either freshly quenched or annealed.

Tensile specimens tested at intervals from 5 minutes to 6 days after quenching (20) show an increase of hardness and tensile strength, but an almost uniform elongation; see Figs. 4 and 5. The elongation of test specimens is evidently not an index of the plasticity (workableness) of the material. It is interesting to note that annealed material has a lower elongation (10 to 14 per cent) than that of the stronger and harder tempered material (18 to 25 per cent) see Table III.

Jeffries and Archer (28) point out that cementite Fe_3C, in steel may have a keying effect in the matrix of ferrite, similar to that of $CuAl_2$ in duralumin. The hardening of duralumin at atmospheric temperatures also has a parallel in the hardening of some of the high carbon manganese and tungsten steels by precipitation of finely divided cementite from austenite when heated to moderate temperatures. (8) (28).

Other Constituents

In the foregoing discussion of hardening only the elements copper and aluminum have been considered. Referring again to Merica (1) (8):— The characteristics of duralumin depend fundamentally upon the constituent $CuAl_2$, but the hardening effect is greatly increased by the presence of the usual small amounts (up to 1 per cent) of magnesium in its composition. Magnesium forms a eutectic with aluminum Mg_4Al_3 whose melting point is about 860 degrees Fahr. and which contains about 36 per cent of Mg. Magnesium enters into solid solution in aluminum, in increasing amounts with temperature up to about 12 per cent at 860 degrees Fahr.

Alloys of aluminum with magnesium alone, in amounts up to 3 per cent Mg do not harden upon ageing. The action of the magnesium in duralumin is to *intensify* the hardening effect of the $CuAl_2$. Here again is an analogy with steel, in the action of small amounts of nickel in increasing the hardening effect of carbon in steel. The exact reason for this intensifying action of magnesium is not clear, but it may be due to its effect upon the silicon or iron which are present as impurities. Magnesium combines with silicon to form Mg_2Si, visible as a blue constituent under the microscope. The removal of the silicon in this manner may increase the hardness of the metal. (1).

Iron forms a eutectic, $FeAl_3$, with aluminum, which is often found to surround particles of $CuAl_2$. Magnesium may lower the melting

temperature of this envelope, thereby allowing the $CuAl_2$ to diffuse more readily in the aluminum.

The eutectic Mg_2Si melts at about 840 degrees Fahr. This, and the melting of the Mg_4Al_3 eutectic, at 860 degrees Fahr. accounts for the hot shortness of duralumin above that temperature. Forging and rolling should therefore be done below 840 degrees Fahr. although the material might be preheated to about 930 degrees Fahr. to dissolve the $CuAl_2$.

The writer has found no explanation of the function of manganese in duralumin. It has been stated that it gives an increase in tensile strength of about 5000 pounds per square inch, and also increases the hardness and decreases the ductility slightly.

Etching

The microscope is much less useful in the study of duralumin than in steel because the changes produced by heat treatment are not visible, even under high magnification. The microscope may be used in the examination of the grain size, microflaws, the effects of working, and the presence of various constituents and impurities, etc. Duralumin is subject to many of the internal structural defects common to steel, such as inclusions, segregations, laminations, blowholes, fissures, pipes, etc.

Many features of the microstructure are visible in the polished section without etching.

Metal polish on broadcloth has been found satisfactory for final polish, and better than rouge or aluminum oxide. The latter are apt to leave a stain. For grain structure etching with 10 per cent sodium hydroxide or 5 per cent hydrofluoric acid is reccommended, while for microconstituents 0.1 per cent sodium hydroxide plus 10 per cent alcohol in water is superior. A 10 per cent solution of nitric acid is useful for some purposes. Sodium carbonate has also been used.

The microconstituents of duralumin are described, with photographs, in references (1) and (8).

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SOME NOTES ON THE INSPECTION OF STEEL FOR AUTOMOBILE USE

By R. J. Allen

IN THE production of any highly developed machine such as the automobile, considerable attention is paid to the dimensional inspection of all parts while but comparatively little attention is paid to the inspection of the quality of material used other than to see that its surface is of the desired hardness and free from seams or cracks. The reason for this is probably twofold; first, inaccurately machined parts, aside from being non-interchangeable, cause trouble in assembly and also prevent the smooth operation demanded by sales, while unsound or improperly heat treated parts do not, in most cases, cause trouble until after they have been in service for some time; second, instruments for checking the dimensions of any machined surface have been developed to a much greater extent than have instruments for peering into the interior of metals so that the inspection of the latter is necessarily more troublesome and uncertain.

Tests of Inspecting Not Extensive Enough

The magnetic analysis and the X-ray offer possibilities for the future, but at the present, aside from surface hardness, all forms of physical tests are more or less destructive in nature and hence cannot readily be applied to the part intended for service. The usual practice, therefore, is to select representative samples from the lot of material as received from the mill, make tests on these, and assume the remainder of the stock to be of the same nature; material accepted by these tests is then passed for use to be worked into forgings or machined parts. If the tests are numerous enough and the results uniformly good it is perhaps logical to assume that the material is satisfactory but subsequent to these tests carelessness on the part of the forgeman through improper hammering or excessive overheating, or carelessness on the part of the heat-treater may leave some of the pieces in such a state, not revealed by the surface condition, that ultimate failure in service must result; the representative tests on the original stock therefore cannot be regarded as a true criterion of the finished part.

To the manufacturer whose reputation is built on the continuity of service of each individual car over long periods of time without replacement or adjustment because of breakage or excessive wear, it is essential that the soundness of each important or highly stressed part be assured before it is passed for service. In vital parts such as steering members where failure may result in serious accident this is doubly important. With present facilities the only reliable, and at the same time practical way, of obtaining this assurance is by means of the individual fracture test; this, while not made on the material actually used in the part, can with the aid of a properly attached prolongation, be carried so close to it that the possibility of variation is indeed slight.

Fracture Tests

The accompanying illustration, Fig. 1, shows a few of the parts of the Rolls-Royce chassis provided with test prolongations. These extensions are left undisturbed until after the pieces have passed all stages of heat treatment and final hardness inspection when they are nicked, fractured off, and ex-

A resume of a talk given before the Providence Chapter. The author, R. J. Allen, is metallurgist, Rolls-Royce Co., Springfield, Mass.

amined. It will be noted that the prolongations are placed so that when fractured they expose a transverse section of the material. Attention is called to the ball-end for steering piece, a part machined from bar stock, with its double prolongation, the upper one when fractured to reveal the depth and refinement of case, the lower one, bent through an angle of 90 degrees, to reveal the ductility of the core.

The fractures illustrated in Fig. 2 were made on two similar forgings forged from the same lot of uniformly good steel. Both pieces had the same

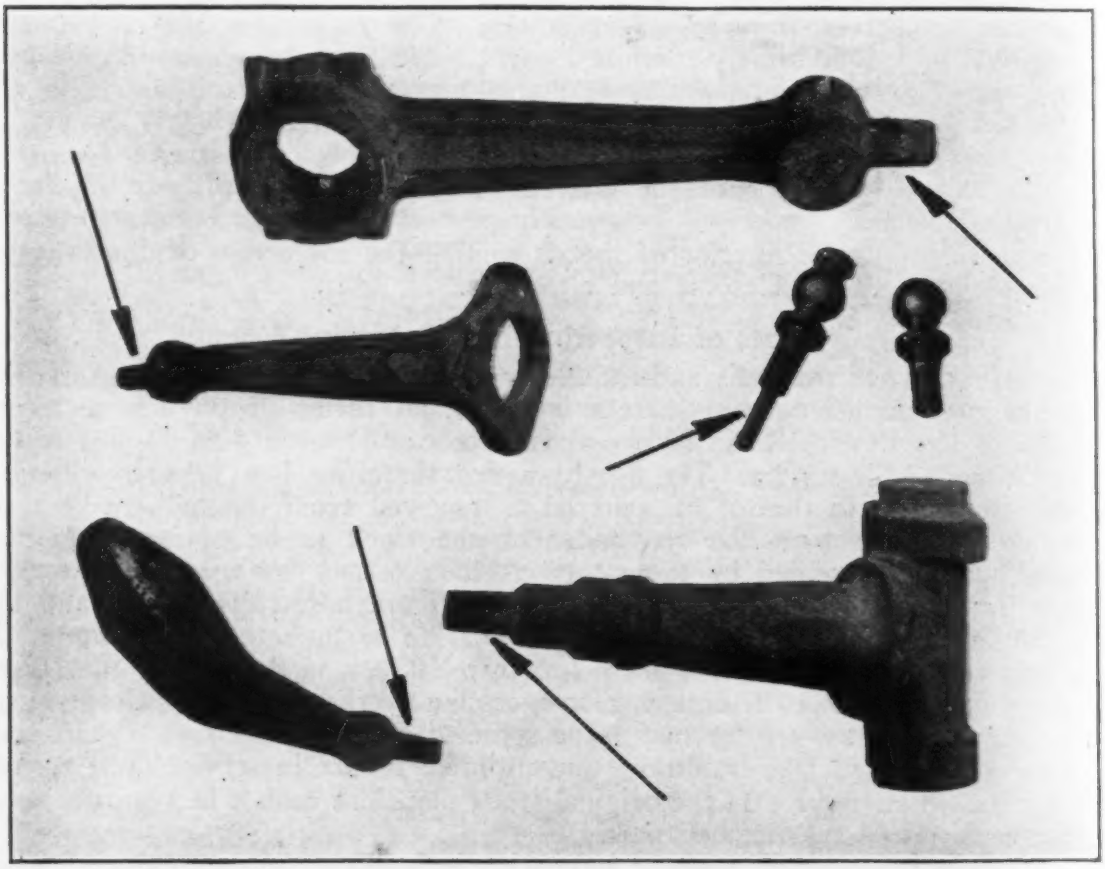

Fig. 1—Method of attaching test prolongations to forgings. The arrows indicate the location of the prolongation.

Brinell hardness following the standard heat treatment and outwardly were in appearance the same. "A" exhibits a good tough condition in the metal while "B" exhibits a decidedly brittle condition due to excessive heating during forging. The fractures on the small test prolongations clearly indicate the condition that existed in the forging proper. A section of the forging in question shows the proximity of the forging fracture to that of the test prolongation. Fracture "B" is representative of the condition of three out of a lot of 200 forgings; the remainder were all acceptable pieces. Without the test prolongations the three, although decidedly inferior to the others, would undoubtedly have been passed for use.

From the appearance of the fracture one can tell whether the material is sound and in the structural condition desired and also one can predict with considerable accuracy the results that would be obtained on a physical test. The prediction as to physical results, however, like the file test for hardness or the color observation for temperature, is not absolute and recourse must

frequently be had to some standard form of physical test just as the feel of the file must be checked against the scleroscope and the color against the pyrometer.

Physical Tests

The forms of physical test, excluding hardness which is nondestructive, against which the fracture may be checked, vary. The value of the tests

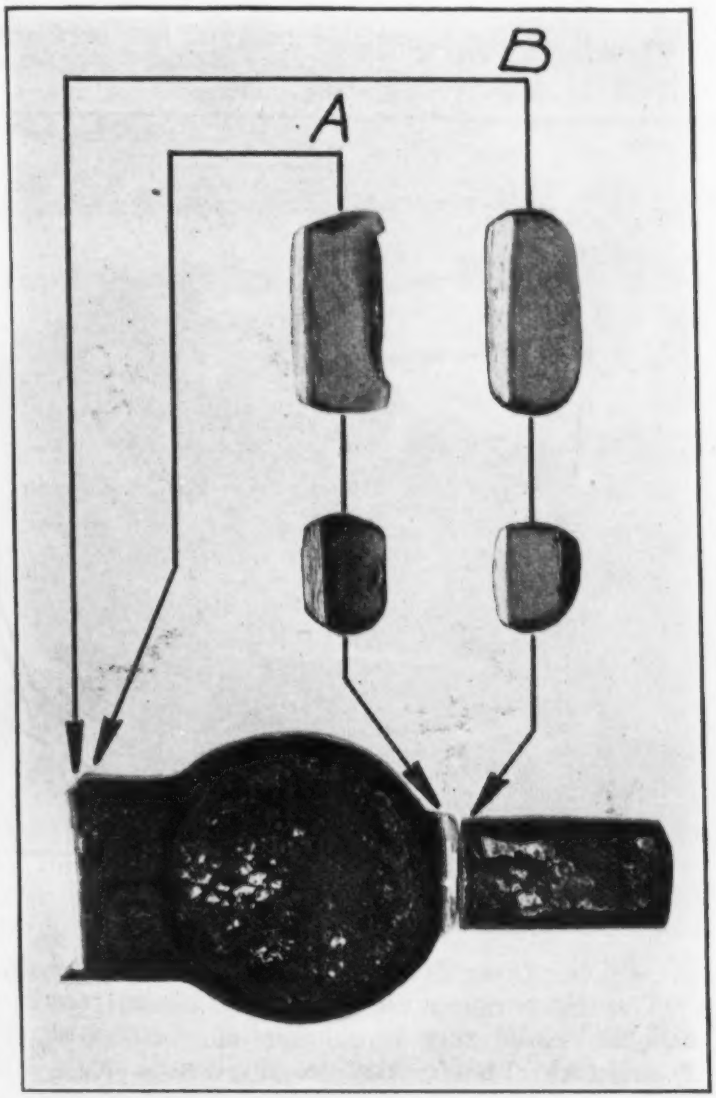

Fig. 2—Shows the manner of using test prolongations. The fracture reveals the structural condition in the forging.

selected, however, depends upon the closeness with which they duplicate actual service conditions. The tensile test is undoubtedly fundamental but its static form of loading does not approximate very closely the condition under which most parts are stressed. Assuming that the design is reasonably correct, it is seldom that a piece snaps off short in service under impact conditions and hence the Izod test, although commonly used, is not representative. Pieces will fail occasionally, however, through fatigue as the result of small blows repeated many times and alternately stressing the fibres in tension and compression; the Stanton test, with its fracture showing all the

characteristics of a fatigue failure, duplicates these conditions closer than any other form of test tried up to the present time.

Repeated Impact Tests

The Stanton machine, of English origin, has been used in conjunction with the tensile with very satisfactory results on individual crankshafts, front axles, and on representative pieces selected from small batches of other parts which in service are subjected to impact and reverse stresses. Its ability to discriminate between suitable and unsuitable material has been demonstrated by

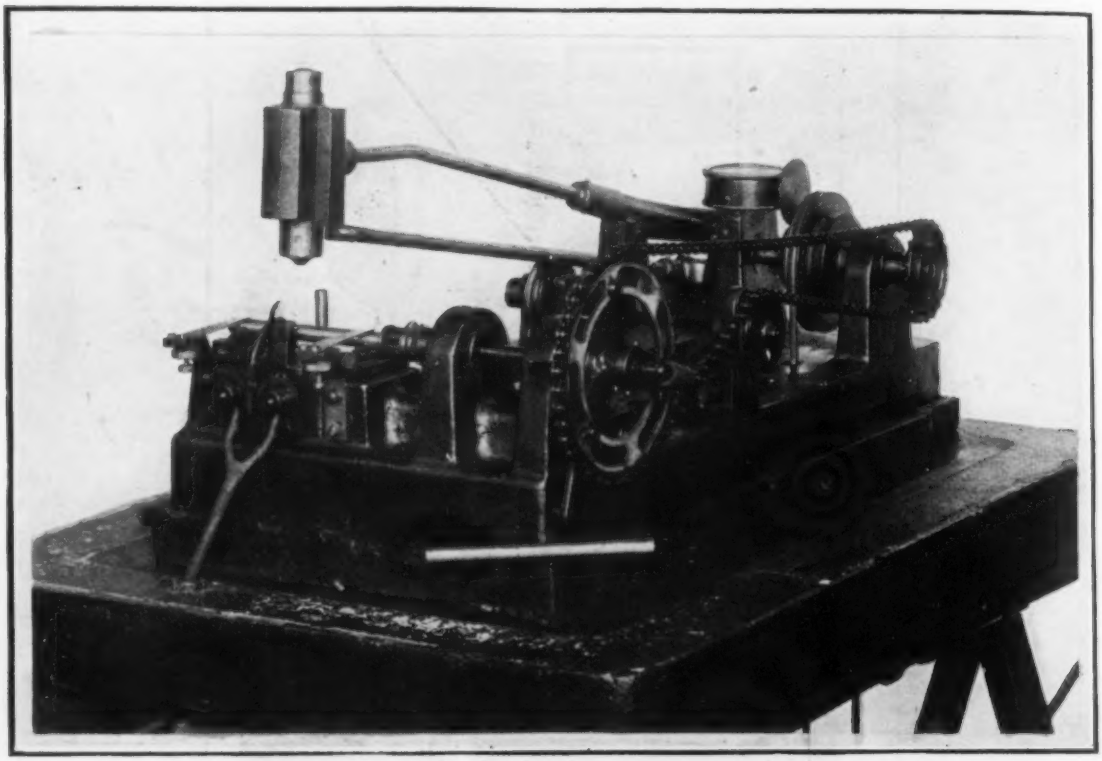

Fig. 3—The Stanton repeated impact testing machine.

the closeness with which its results check life tests made on finished units such as road springs. The test is rather unique in that, aside from duplicating service conditions, reliable results may be obtained in a comparatively short time, about one hour, and also results may be duplicated with considerable accuracy, which is not the case with most impact forms of test. The principle of the test is being made use of by some American instrument manufacturers, and machines, slightly modified in form, are being offered for use.

The Stanton machine is illustrated in the accompanying photograph, Fig. 3. The test piece, which is one-half inch in diameter and six inches long, has a fifty-thousandths square groove cut around its periphery near the center in order to localize the stresses. The piece, placed on two anvil supports some four and one-half inches apart, is set with the groove midway between the supports and directly under the hammer. The hammer is raised by means of a cam to the desired height, usually two inches, from which it falls by gravitation onto the test piece at the rate of one hundred blows per minute. Each

(*Continued on Page 97*)

BIBLIOGRAPHY OF HIGH SPEED TOOL STEELS

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Structure of High-Speed Steels. (In Engineering, Vol. 98, p. 90.) Editorial referring to papers of Le Chatelier and Osmond in Bull. Soc. Encouragement pour l'Industrie Nationale.

1905

The Types of Structure and the Critical Ranges on Heating and Cooling of High Speed Tool Steels Under Varying Thermal Conditions. By H. C. H. Carpentier. (In Journal Iron and Steel Institute, 1905, pt. 1, p. 433-73, 4 plates, 7 inserts, abstract Mechanical Engineering, Vol. 15, p. 315-16.) Concludes that the hardening of rapid tool steel involves the widening, splitting, or lowering of the critical ranges of the special alloy element, and the complete suppression of the widened, split, or lowered range by a mild quenching.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil., 47, p. 105-8.) Tool steels for high speed Preparation and use in the shops. Composition, influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A. W." steel.

High-Speed Tool Steels and Low Carbon Alloys. (In Iron Age, Vol. 75, p. 1733.) Use of ferrotungsten causing oxidation because of carbon impurity content, made high-speed steel of uncertain analysis.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industriele, Vol. 1905, p. 315-6, 223-4, 338-9, 358-9, Mem. Soc. Civ. de France pt. 1, p. 919-35.) P. 315. Definition, history, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, that transformation point A^1; p. 338, composition of high-speed steel, constitution of chromium and of tungsten steels; p. 358-9, transformation points of chrome-tungsten steel an influence of the constituents; p. 368, properties treatment, results obtained at Manchester and at Birmingham.

Wolfram-und Rapidstahl. By A. Ledebur. (In Stahl und Eisen, Vol. 25, p. 768-9.) Tungsten and Rapid Steel. Theory of the influence of tungsten on self-hardening or rapid steels.

A New Hardening Furnace. (In American Machinist, Vol. 28, p. 354-5.) Brayshaw furnace for use in hardening steel. Fig. 4, heating and cooling curve of Seebohm and Dieckstahls N. C. High-Speed Steel.

1906

Quarternary Steels. By Leon Guillet. (In Journal Iron and Steel Institute, pt. 2, p. 1-141, 1 insert.) Research to systematize the use of quarternary steels, or an alloy of iron, carbon and two other added elements.

Dokter Bohlers Studien Uber den Rapid-Stahl. By F. Kick. (In Zeitung des Oesterr Ing. in Arch. Ver. v. 58, p. 267-9.) Discussion of thesis of O. Böhler on Rapid Steel before the group of machine engineers of the Vereins-Angelegenheiten.

Die Entwichlung des Schnellarbeistahles in Deuschland. By O. Thallner. (In Zeitung des Verein deut. Ing. vol. 50, p. 1690-7, 1 insert.) The development of high speed steel in Germany. The introduction of the Taylor-White Process, outline of process, chemical composition of high speed steel, influence of car-

bon, chromium tungsten, molybdenum, silicon, new knowledge on the relation between chemical composition and the hardening effect; the high speed steels in use.

1907

The **Theory of High-Speed Tool Steel.** By G. Auchy. (In Iron Age, Vol. 80, p. 1818-22.) Conclusions drawn from a comparison of theories of Osmond, Böhler, Le Chatelier Carpenter. Arnold, Guillet and Taylor.

The **Making of High-Speed Steel Tools.** By O. M. Becker. (In American Machinist, 30 pt. 1, p. 411-4.) Discusses forging, kind of furnace, heating for hardening, the oil bath, method of dipping, degree of hardness desired, tempering furnace.

An **Analysis of the Evolution of Modern Tool-Steel.** By H. C. H. Carpenter. (In Engineering, Vol. 83, p. 569-71, 633-4.) Current theories of hardening, the wear of tools in cutting metals, epochs in the history of tool-steels, possible future developments. Refers especially to F. W. Taylor's work on the "Art of Cutting Metals."

Sur **un Nouvel Acier a Outil au Chrome**. By L. Guillet. In Revue de Metallurgie Mem., Vol. 7, p. 1025-6.) A new tool-steel using chromium, microphotographs, analyses.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E., Vol. 28, p. 31-279; disc. p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie. Mem., Vol. 4, p. 39-65, 108-84, 233-336, 401-66, abstract in Engineering, Vol. 83, p. 54-5, abstract in American Machinist, Vol. 30, pt. 42-6, 215-9, 257-51.) P. 222-64 Modern high speed tools using high speed steel, chemical composition of tool-steels for high speed, discovery of high-speed steel, American Machinist extracts those parts of practical shop value.

1908

The **Manufacture of High-Speed Steel.** By O. M. Becker. (In Cassier's Magazine, Vol. 34, p. 291-9.) Charging of crucible, melting hole, heating and pouring of the melt, molding the ingot, annealing costs.

Possible Methods of Improving Modern High-Speed Turning Tools. By H. C. H. Carpenter. (In Transactions Manchester Association Engineers, p. 1908-9, p. 81-100, disc. pt. 111-2, 2 plates.) abstract in Engineering, Vol. 206, p. 588-9. Composition, manufacture, heat treatment of high speed tools, manufacture of tool steel in electric furnaces, welding high-speed to mild steel, summarizes possible improvements in manufacture and composition of high speed steel.

Function of Chromium and Tungsten in High-Speed Tool Steel. By C. A. Edwards. (In Journal Iron and Steel Inst., 1908, pt. 2, p. 104-32, 6 inserts, 5 plates; abstracted in Engineering, Vol. 85, p. 717; Mechanical Engineering, Vol. 21, p. 723.) Concludes that function of chromium is to form a double carbide with tungsten which imparts to these steels a very high degree of hardness and increases the resistance to tempering.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346-50, 361-3.) Manufacture and use of tools of high speed steel. Discussion of paper by A. L. Valentine in the American Machinist includes composition of high speed steels, analyses, tools used in test, factors which in-

fluence the cutting speed, economic results, hardening high speed steel, determination of the temperature uses of high speed steel and economics which result from its use.

High-Speed Tool Manufacture. (In Mechanical Engineering, Vol. 22, p. 73) Patent of A. G. Ludwig, Berlin, of fusing high-speed steel cutting edge to shaft of ordinary steel.

A New System of Welding. (In Engineering, Vol. 85, p. 822-3.) Welding of high speed steel onto carbon steel.

La Dureté à Chaud des Aciers. By Robin. (In Revue de Metallurgie Mem., Vol. 5, p. 893-908). The hardness of steels when hot. P. 906-8. Study of high-speed steels, cooling curves.

Ueber Dreharbeit und Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin. J. Springer. Translation of "On the Art of Cutting Metals" reviewed in Zeitung des Ver. Deut. Ing., Vol. 52, p. 970.)

Making and Using of High-Speed Steel Tools. By A. L. Valentine. (In American Machinist, Vol. 30, pt. 2, p. 6-9.) Composition of metal, forging, grinding and tempering of lathes, tools and milling cutters.

1909

The Newer Sheffield Steels. By O. M. Becker. (In American Machinist, Vol. 32, pt. 2, p. 264.) Brief description of tests on new high-speed steels of W. Jessop & Sons, Ltd., Strong Twist Drill Co., and Darwin & Milner, Sheffield.

English Versus American High-Speed Steels. By E. T. Clarage. (In American Machinist, Vol. 32, pt. 1 p. 1031-2.) Explanation of the hardening of carbon steels, of high speed steels, and discussion of the progress made by American manufacturers over that of English.

Science Demands Recognition in the Arts. By E. T. Clarage. (In Iron Trade Review, Vol. 44, p. 723-4.) Arguments concerning manufacture of high-speed tool steel, disputing statement in the Engineer placing all responsibility for the success of the new steels on the workman, rather than on the steel maker.

The Special Steels in Theory and Practice. By W. Giesen. (In Iron and Steel Inst., Carnegie Scholarship Memoirs, Vol. 1, p. 1-59.) P. 44-7. The theory of the ferro-carbon of the ferro-carbon alloys and high speed cutting steels.

High-Speed Steel Patent Case. (In Mechanical Engineering, Vol. 23, p. 229-30.) Decision of the case of the Bethlehem Steel Co. vs. Niles Bement Pond Co., in which the former, who worked the patents granted to Taylor and White sought to restrain the defendants from manufacturing high-speed steel. Question depended upon the term "breaking down point."

High-Speed Steel. (In Engineering, Vol. 107, p. 174.) Decision of judge in the case on the charge of infringement of a patent for high speed steel brought by the Bethlehem Steel Co. against the Niles Bement Pond Co., in favor of latter.

Manufacture of Tools of High-Speed Steel. (In Mechanical Engineering, Vol. 23, p. 135.) Tools with working portion of high-speed steel, and the body portion of unordinary steel by process patented by Paul A. Viallon, Paris.

A New Steel. (In Engineering, Vol. 86, p. 190; American Machinist, Vol. 32, pt. 1, p. 337.) New high speed steel which is hardened in water of Jonas N. Culver of the Continental Steel Works Experiments leading up to discovery.

A **New Tool Steel.** (In American Machinist, Vol. 32, pt. 1, p. 241.) "Nove Superior" made by Continental Iron & Steel Co., Sheffield, Eng., as result of experiments due to the litigation over the Tavlor-White high-speed steel patents.

Tool **Steel Sensation.**. (In Engineering, Vol. 107, p. 243-4; American Machinist, Vol. 32, pt. 1, p. 495.) Editorial on announcement of new water hardened tool steel by Prof. Arnold, its effect commercially and technically.

1910

Development and Use of the New High-Speed Steel. By W. Carter. (In Engineering, Vol. 109, p. 154-5; Mach. Engr., Vol. 25, p. 191-3; abstracted in Stahl und Eisen, Vol. 30, p. 543; abstracted in Iron Trade Review, Vol. 46, p. 480-3.) Paper before Birmingham Association of Mechanical Engineers. Development, composition, heat treatment and use of new high speed steels containing vanadium.

High-Speed Steel. By O. M. Becker. (In N. Y. McGraw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high speed tools, analyses of high speed and special steels. reference table for determining cutting speeds.

High-Speed Tool Steel. By W. V. Brandt. (In Iron Age, Vol. 86, p. 1025; Mechanical Engineering, Vol. 27, p. 38.) Method of manufacture and heat treatment.

High-Speed Steel Tools. (In Iron Age, Vol. 85, p. 434-7.) Welded Tools, joining by compression, by brazing, inserted tooth saws, milling cutters and drills, compound steel reamers.

High-Speed Steel and Its Heat Treatment. By W. G. Smith. (In Mechanical Engineering, Vol. 26, p. 537-50.) Abstract of article in "The Armour Engineer" history of high-speed steel, influence of carbon, chromium, tungsten, molybdenum, silicon, method of forging, tempering, the barium chloride process, and quenching.

Tool **Steel Welding.** By W. F. Stanton (In Iron Age, Vol. 86, p. 987.) Method of welding a cutting edge of high speed steel onto tools made of common machinery steel.

Die **Schule des Werkzeugmachers.** By F. Schon. (In Hanover. M. Janecke, 156 pp.) Test-book for toolmakers, p. 120-33, high speed steel, the influences of rapid steels on the construction of tools and machines, grinding of high speed steel tools.

1911

Influence of 0.2 Per Cent Vanadium on Steels of Varying Carbon Content. By A. McWilliam, and E. J. Barnes. (In Eng., Vol. 91, p. 652-4; Iron and Steel Institute Journal, Vol. 83, p. 294-310; disc. p. 311-17.) Research on the comparative influence of vanadium on cutting steels and on chromium, tungsten, nickel and plain structural steels.

1912

The **Chemical and Mechanical Relations of Iron, Vanadium, and Carbon.** By J. O. Arnold, and A. A. Mead. (In Journal Iron & Steel Institute, Vol. 85, p. 213-23, disc. 227-34; Engineering, Vol. 98, p. 784-6.) Report of research to determine the composition of the carbides separated from a series of well-annealed steels containing various percentages of vanadium, the mechanical properties and the microscopical features of the alloys.

Composition of High-Speed Tool Steel. By E. T. Edwards. (In Iron Age, Vol. 89, p. 957-60; Mechanical Engineering, Vol. 29, p. 552-5.) Performance of high-speed Tool steels, of superior high speed steels, the part played by Vanadium, method of testing tool steels, tests made by author.

Microscopic Study of High-Speed Steel Tools. By F. Fettweis. (In Stahl und Eisen, Vol. 32, p. 1866-7; abstr. in Iron Age, Vol. 91, p. 189-91, 2 plates.) Carbon conditions as revealed by use of special etching solutions on chromium steel, carbon-tungsten-chromium steels, and high percentage alloy steel.

Tool Steel for the United States Navy. By L. H. Kenney. (In Transactions Soc. Nav. Arch. & Mar. Engrs., Vol. 20, p. 345-75; abstr. in Iron Age, Vol. 91, p. 839-41; Mechanical Engineering, Vol. 31, p. 401-3; Iron Trade Review, Vol. 52, p. 689-91.) P. 346-9. Specifications, development, use of tungsten tool steel, or high speed steel; p. 351-2. Selective tests on tungsten tool steel; p. 357-9. Specifications for high speed steel issued by the Navy Dept., Jan. 5, 1909; p. 362-3. Specifications for high-speed steel for U. S. Naval Academy; p. 364-75. Specifications for tool steel issued by the Navy Dept., July 20, 1911.

Manufacture of Lincoln-Williams Twist Drills. By C. L. Lucas. (In Machinery, Vol. 18, p. 515-9.) Details of process using either high-speed or carbon steels.

Die Spizialstähle. By G. Mars. Stuttgart. Ferdinand Duke. 517 pp. Special steels, p. 387, high speed steels, self-hardening, Taylor-White process, composition of various high speed steels.

Composition of High-Speed Tool Steel. By J. A. Mathews. (In Iron Age, Vol. 89, p. 1098-9.) Letter referring to paper by E. T. Edwards, Iron Age, Vol 89, p. 957, differing with Mr. Edwards as to the time of the introduction of vanadium into high-speed steels.

Vanadium in High-Speed Steel. (In Machinery, Vol. 18, p. 837.) Effect of varying amounts of vanadium from 0.2-1.0 per cent, on cutting speed of high-speed steel, figures given by American Vanadium Co.

1913

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, Vol. 45, p. 833-42; Vol. 46, p. 63-76. 194-200, 400-15, 931-42.) P. 883-42, theory of hardening, factors conducive to cutting speed, development of tool steels and alloys. P. 63-76, processes of manufacture, mechanical treatment, machinery and equipment used. P. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers. P. 931-42, machine-tool operation at high cutting speeds, inserts.

Recent Advances in Scientific Steel Metallurgy. By J. O. Arnold. (In Engineering, Vol. 95, p. 162, Mechanical Engineering, Vol. 31, p. 153-4.) Paper read before the Royal Institution, traces the development of Mushet high-speed and vanadium high-speed steels. Table gives comparative cutting powers of Huntsman-low-grade, and high-grade high-speed steels.

Structure des Aciers et Modifications Accompagnant les Traitments Thermique. By De Nolly. (In Bull. Soc. l'Ind. Min., Vol. 4, p. 371-82. 8 plates.) Structure of steels and modifications accompanying the heat treatment. Point of transformation, theory of hardening, use of microscope, dilation curves of a high-speed steel, heated to 850 degrees, 7050 degrees Cent.

Die **Fortschritte Deutscher.** (Stahl und Eisen, Vol. 33, p. 1196-1204, 1363-4, 1403.) Discussion on Schlesinger's paper, "The progress of German Steel Works in high alloyed rapid steels," by Poldihutte, Schlesinger, E. Kothny, and the steel firms involved.

Composition of High-Speed Tool Steel. By E. T. Edwards. (In Iron Age, Vol. 89, p. 937-60; Mechanical Engineering, Vol. 29, p. 552-5.) Performance of high speed steels of superior high-speed steels, the part played by vanadium, method of testing tool steels, tests made by author.

Die **Fortschritte Deutscher Stahlwerke bei der Herstellung Hochlegierter Schnollarbeitsstahle.** By G. Schlesinger. (In Stahl und Eisen, Vol. 33, p. 929-39; abstr. in Iron Age, Vol. 92, p. 33.) The progress in German steel works of the production of high-alloyed rapid working steels, considering especially the effect of cobalt. Tests on cobalt high speed tool steel at Royal Technical High School, Berlin.

1914

Behavior of Iron in Some Alloys. (In Iron Trade Review, Vol. 55, p 526, 5606. Abstract of papers and discussion on "The Chemical and Mechanical Relations of Iron, Tungsten, and Carbon, and of Iron, Tungsten, and Nickel" by A. A. Read and J. O. Arnold before the Institutions of Mechanical Engineers.

Built-Up High-Speed Steel Cutting Tools. (In Iron Age, Vol. 93, p. 1124-5). Process developed by Adolph Rosner of Bridgeport, Conn., of welding high-speed steel to low-grade carbon steel. Costs.

Etude sur les Propietes Generales des Aciers a Outils. By Denis. (In Revue de Metallurgy Mem., Vol 11, p. 569-669; abstr. in Journal Amer. Spc. Mech. Eng., Vol. 36, p. 0164-6.) Investigation into the general properties of tool steel, discussing the method of tests and heat treatment of various kinds of tool steels, detailed data of the tests, and conclusions from this data.

Note on the Transformations of Steels. By H. De Nolly and L. Veyret. (In Journal Iron and Steel Inst., Vol. 90, p. 165-80; Engineering, Vol. 98, p. 631-3.) Discussion of the carbide theory, the allotropic theory, and a theory of the dissociation of the carbide accompanied by the solid solution in the iron, of the carbon liberated by this association, proposed by the authors, and illustration by curves of critical points of high speed tool steel.

Ueber die Analyse von Schnelldrehstahl. By F. Fettwies. (In Stahl und Eisen, Vol. 34, p. 274 and 275.) On the analyses of high-speed steel. Presented before the chemical committee of the Vereins deutscher Eisenhuttenleute. Discussion.

Gegossene Schnelldrehstahle. (In Stahl und Eisen, Vol. 34, p. 1306-7.) Casting high-speed steels, forging, tempering to tools.

Qualques Essais de Duree avec des Aciers Rapides. By R. Poliakoff. (In Werkstattstechnik, Feb. 1, 1914, abstr. in Bull Soc. D'Encour., Vol. 121, p. 659-60.) Some tests on durability of high speed steels. Table giving chemical composition of steels tested.

Welding High-Speed to Ordinary Steel. (In Iron Age, Vol. 4, p. 152.) It is necessary to prevent the weld from cooling between the time it is made and the annealing. Temperature should not drop below 1200 degrees Fahr.

1915

Experiments on the Corrosion of Molybdenum. By L. Aitchison. (In Journal American Chemical Society, Vol. 107, p. 1531-8.) Addition of molybdenum to pure carbon steel results in a definite increase of corrosion until very high percentages are reached.

The Chemical and Mechanical Relations of Iron, Cobalt and Carbon. By J. O. Arnold and A. A. Read. (Inst. Mech. Engrs. 1915, p. 629-51; Engineering, Vol. 99, p. 362-4, disc. p. 346-8.) Theory microphotograps and tests referring especially to the carbides of cobalt

Failures of High-Speed Steels. By G. J. Brunelle. (In Railway Age Gazette Mech. Ed. p. 89, 369-70; Mechanical Engineering, Vol. 36, p. 238-40.) Failures due to forging, heat-treating, grinding and abuse.

The Thermo-Electric Properties of Special Steels. By E. L. Dupuy and A. M. Portevin. (In Journal Iron and Steel Institute, Vol. 91, p. 306-35.) Tests on nickel, chromium, manganese, aluminum, silicon, tungsten, molybdenum steels.

Manufacture and Uses of Alloy Steels. By H. D. Hibbard. (In U. S. Bureau of Mines Bull. 100, 77 pp. Extract Mechanical Engineering, Vol. 38, p. 4-6, 31-2.) P. 53-67. High speed steels including manufacture, composition, effect of carbon, chromium, tungsten, molybdenum, cobalt, copper, sulphur and phosphorus in high speed steel, heat-treatment, theory-patents and bibliography.

High-Speed Steel Alloys. (In Engineering, Vol. 102, p. 509-10.) Editorial on the Ed., Vol. 89, p. 590.) Welding high-speed steel tips on shanks or holders made of axle or tire steel.

1916

German High-Speed Steel. (In Iron Age, Vol. 98, p. 1111, quotations from Elektrotechnische Rundschau.) Composition of high speed steel for lathe tools, brief outline of hardening process.

High-Speed Steel Alloys. (In Engineering, Vol. 102, p. 509-10.) Editorial on the supply of tungsten for use in making high speed steels.

High Speed Steels Without Tungsten. (In Iron Age, Vol. 97, p. 1527.) Darwin and Milner steel containing neither tungsten, molybdenum, cobalt or vanadium, and German tungstenless high-speed steel of Richard Lindenberg Steel works at Remshied.

The Transformations of Special Steels at High Temperatures. By K. K. Honda, Tawara and H. Takagi. (In Journal Iron and Steel Inst., Vol. 93, p. 224-54, 3 plates. Investigation on carbon steels, D. S. W. Steel, Ultra Capital Seebohm, New Capital Seebohm, Bohler Super-Rapid Novo, and Becher Diamond Steels.

Molybdenum: Its Ores and Their Concentration. By F. W. Horton. U. S. Bureau Mines Bull. 111., 132 pp. P. 21-25. Molybdenum steels, use of molybdenum in tool steels.

New High-Speed Steels. (In Mechanical Engineering, Vol. 37, p. 394-5.) Editorial announcing that Darwin & Milner had discovered an alloy substitute for high-speed steel that contains neither tungsten, cobalt, molybdenum or vanadium.

The New British High-Speed Steel. (In Iron Age, Vol. 98, p. 55.) "Reactol" steel contains neither tungsten nor cobalt, and requires neither forging, hardening nor tempering, produced in Sheffield.

Producing Lathe Tools Autogenously. (In Iron Age, Vol. 97, p. 902; Mechanical Engineering, Vol. 37, p. 372.) System of welding high-speed to carbon steel at the Topeka shops of the Atchison, Topeka, and Santa Fe Railway Co.

A New High-Speed Tool Steel. (In Engineering, Vol. 101, p. 510.) New steel containing neither tungsten, molybdenum or cobalt, cast to desired form, ground on an emery-wheel (dry), finished on a wet grindstone, and is ready for use, made by Darwin and Milner, Sheffield.

Reclaiming High-Speed Steel. (In Iron Age, Vol. 97, p.1032) Onondaga Steel Co., Syracuse, N. Y., takes odds and ends of high speed steel and forges them into tool bits.

Uranium in Tool Steel. (In Iron Age, Vol. 97, p. 952; Iron Trade Review, Vol. 59, p. 4771. Comparative tests of uranium and other high-speed steels, by Standard Chemical Co., Pittsburgh.

Welded High-Speed Steel Cutting Tools. (In Iron Age, Vol. 97, p. 700.) Brief description of incandescent welding of high-speed steel to hot and cold rolled steel bars and to ordinary tool steel by the Westinghouse Electric and Manufacturing Co.

1917

Cobalterom, the New Steel Alloy. (In Engineering, Vol. 104, p. 22.) New high-speed steel alloy which does not contain tungsten, discovered and patented by Darwin & Milner. Maximum heat necessary for hardening is only 1000 degrees Cent. Cools naturally in still air.

The Penetration of the Hardening Effect in Chromium and Copper Steels. By L. Grenet. (In Journal Iron and Steel Institute, Vol. 95, p. 107-14, disc. p. 115-7, abstr. in Iron Age, Vol. 100, p. 808-9.) Effect of chromium, copper and nickel on the penertation of the hardening.

Emploi des Outils en Aciers Moule Rapide. By L. Grenet. (In Revue de Metallurgie Memoirs, Vol. 14, p. 547-50, abstr. in Iron Age, Vol. 101, p.1204.) Cast high-speed tool steels, tests on extra hard, hard, and normal steel at the Firming steel works.

A High-Speed Tool Steel Patent Action. (In Engineers, Vol. 123, p. 412.) Action for the revocation of British Pat. No. 27838 of 1912, granted to the Stahlwerk Becker Aktiongesellschaft of Krefehd-Willich, Germany, for a steel containing cobalt.

Two New High-Speed Steel Tools. (In Iron Age, Vol. 100, p. 655.) Abstract of U. S. Pat. 1,233,118 by James H. Parker for tungsten-chromium vanadium steel and of U. S. Pat. 1,233,862 of Radclyffe Furnace for addition of cobalt and tungsten to high-speed tool steel containing tungsten, chromium, and vanadium to increase cutting efficiency.

1918

Liquid Steel. By D. Carnegie. 2nd. Ed. N. Y. Longsman Green and Co., 526 pp. P. 106-9, cost of crucible steel for carbon and high speed tools. p. 112-5, composition of high speed steels charges.

Cobalt High-Speed Steel Not a German Discovery. (In Iron Age, Vol. 101, p. 321.) Discussion and quotation from the Ironmonger concerning the relocation of

the German patent on cobalt tool steel, as result of decision of British court in the action brought by the Dannamore Steel works of Sheffield.

Quelques Observations Sur "Le Stellite." By L. Guillet and H. Godfroid. (In Revue de Metallurgie, Vol. 15, p. 339-46, abstr. in Iron Age, Vol. 102, p.1584-5.) Some observations on stellite including comparison made of the variation in hardness at different temperature of stellite and a superior quality of high-speed steel.

How Small Tools Were Made Quickly. (In Iron Trade Review, Vol. 62, p. 858-9.) Method for making high-speed steel reamers developed in Jackson, Tenn., shop of Illinois Central Railroad.

The New Cobalt Tool Steel. (In Iron Age, Vol. 91, p. 1477.) Mention of a detailed report of extensive comparative tests of the new German cobalt steel with other tool steels, sent out by the Becker Steel Co. of America.

New High-Speed Tool Steel High in Cobalt. (In Iron Age, Vol. 101, p. 743.) U. S. Pat. 1, 233,118 of J. H. Parker and B. H. Delong of New high-speed alloy steel containing 30 per cent cobalt, 2 per cent vanadium, 3.5 per cent chromium, 12 per cent tungsten, 0.35 per cent carbon.

Iron and Steel. By E. Oberg and F. D. Jones. (In N. Y. Industrial press. 328 pp.) P. 276-97, High Speed Steel, includes origin, Taylor-White process of heat-treatment production of high speed steel, effect of different elements in high speed steels, hardening practice, tempering, annealing, uses.

Molybdenum Seel Versus Gun Erosion. By M. Okochi, M. Kanima, N. Sato. (In Journal College of Eng. Tokyo Imperial Univ., Vol. 9, p. 153-95, Journal Soc. Mech. Engr. Tokyo, Vol. 22, p. 1-44, No. 54.) Experimental determination of modulus of elasticity, modolus of rigidity, Brinell hardness number, thermal dilation, thermal conductivity, and magnetization at high temperatures of specimens of gun steel, nickel steel, nickel-molybdenum steel and tungsten steel.

The Salvaging of High-Speed Steel. (In Iron Trade Review, Vol. 62, p. 845-8.) Practical methods for conserving this valuable material, resmelting, building up tools, electric butt-welding tools.

Resherches sur l'Acier a Couple Rapide Faites au Labora toire du Harvard. By M. Yatesevitch, translated by H. Herbert. (In Revue de Metallurgie Memoirs, Vol. 15, p. 65-109, bibliography 109-115.) Research on high-speed steel made at the laboratory at Harvard. Study on the "Dreadnaught" steel of the Halcomb Steel Co., on determination of the modification in structures and caused by heating and cooling under various conditions, microscopic study of heat-treatment, relation between hardness and heat-treatment.

1919

The Manufacture of Working of High-Speed Steel. By J. H. Andrew and G. W. Green. (In Journal Iron and Steel Institute, Vol. 99, p. 305-26, disc. p. 337-44, 6 plates, 1 insert; abstr. Iron Age, Vol. 104, p. 703-7; Engineering, Vol. 107, p. 688-70.) Practical application of scientific methods to high-speed steel practice, following through the steel from the state of ingot to the finished tool.

The Molecular Constitutions of High-Speed Tool Steels and Their Correlation with Lathe Efficiencies. By J. W. Arnold and F. Ibbotson. (In Journal of Iron and Steel Institute, Vol. 99, P. 407-28, disc. p. 429-35, 2 plates, 1 insert; abstr. In Iron Trade Review, Vol. 64, p. 1419 to 1421.) The Chemical constitutions of

high-speed steels, correlation of the chemical and micrographic analyses with lathe efficiencies of the series. Note on surface tension effects in high-speed steels by F. C. Thompson.

Metallic Alloys. By G. H. Gullever. 3rd Ed. London, C. Griffin & Co. 410 pp. P. 329, brief mention of high speed tool steel under quaternary steels.

Manufacture and Use of Alloy Steels. By H. D. Hibbard. J. Wiley & Sons, N. Y., 96 pp. P. 68-87, manufacture, composition, heat treatment, theory, testing, using and patents of high speed steels. Bibliography.

Favorable Results from Cobalt. By N. B. Hoffman. (In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 177-179; Iron Age, Vol. 104, p. 21-2.) Discussion of Dr. Mathew's paper. Analyses and tests of high-speed steel containing cobalt.

The **Properties of High-Speed Steel.** By G. J. Horvitz. (In Journal Amer. Steel Treaters' Soc., Vol. 2, p. 342-48; abstr. Iron Age, Vol. 103, p. 1711-4.) Composition, crucible and electric processes of manufacture, hardening, heat treatment, theory of hardening, physical properties. 13 microphotographs.

Davidson Process of Casting Formed Tools. By J. F. Johnson. (In Bull. 146, A. I. M. E., p. 353-60; abstr. in Iron Age, Vol. 103, p. 481-3.) A cast tool steel claimed to have the properties of a high speed steel.

Manufacture of Modern High-Speed Steel. By J. A. Mathews. (In Proceedings Amer. Soc. Testing Materials Proc., Vol. 19, p. 141-56; Iron Age, Vol. 104, p. 17-20; abstr. in Metaux, Alliazes et Machines, Vol. 13, p. 8, No. 2.) Evolution from air-hardening steel, effects of chromium and tungsten, detection of overheating, recent disc of vanadium.

High Cobalt Content and High Drawing Temperatures. By J. H. Parker. In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 159-61; Iron Age, Vol. 104, p. 201.) Discussion of Dr. Mathew's paper, concerning use of vanadium and cobalt and of the value of chemical analyses.

Specifications for High-Speed Steels. By R. Poliakoff. (In Iron Age, Vol. 103, p. 827-9.) Summarizes opinions of four European manufacturers on thirteen requirements to be considered in working out specifications for delivery, dealing especially with the test tools.

Standardizing of Practice Important. By. E. W. Rettew, (In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 176-7; Iron Age, Vol. 104, p. 21.) Table of limits and desired analysis resulting from study of high speed steel analyses.

Physical Properties of High Chrome Steel. By L. R. Seidell and G. J. Horbitz. (In Iron Age, Vol. 103, p. 291-4.) Relation between hardness and double carbides in solutions, maximum tensile strength and ductility.

Tungstenless Tool Steel. (In Ironmonger, Vol. 169, p. 86-87, Dec. 27; Raw Material, Vol. 2, p. 60-1.) Use of Prof. J. O. Arnold of 6 per cent molybdenum for 18 per cent tungsten in high speed steel, with one-fourth per cent vanadium as a molybdenum stabilizer.

1920

The **Properties of Water Quenched Vanadium-Molybdenum High-Speed Steel.** By J. O. Arnold. (In Engineering, Vol. 128, p. 480.) Properties of a high-speed steel, patented under a sealed patent in September, 1919, substituted for tungsten, molybdenum associated with a little over 1 per cent of vanadium, the key

element of the chemical composition. The vanadium appears to stabilize the variable properties of molybdenum steel, and to prevent cracking during the water-hardening operation.

On the Structural Constitution of High-Speed Steel Containing Chromium and Tungsten and the Effect of these Elements on Its Hardening and Tempering. By K. Honda, and T. Murakami. (In Science Report of the Tokoku Imperial University, Vol. 9, p. 143-68, 7 plates; Journal Iron and Steel Inst. Reprint 15.) Object of research is to ascertain the structural constitution of high-speed steel, the change of these constituents during heating and cooling, the effect of these constituents upon hardening and tempering.

Reclaiming and Using Broken High-Speed Tools. By J. A. Hope. (In Can. Mach., Vol. 23, 312-313.) Construction of remelting furnace, crucibles, molds, drawing out of ingot procedure in melting; costs.

Making Forged High-Speed Twist Drills. By J. V. Hunter. (In American Machinist, Vol. 52, p. 719-22.) Methods used by Kettler, Elliot Erection Co., Chicago.

A Comparative Test Upon High-Speed Steels. By A. J. Langhammer. (In Chemical and Metallurgical Engineering, Vol. 22, p. 829-32, p. 889-92, 939-42; American Machinist, Vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel, stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of marker's recommendations for treating lathe and planes tools. P. 889, conditions entering into the testing of a tool for cutting as listed by Taylor are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel, p. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition, heat-treatment and hardness.

High-Speed Steel Drop Forgings for Milling Cutters and Special Tools. By A. F. MacFarlan. (In Journal American Steel Treaters Soc., Vol. 2, p. 279-87.) Advantages claimed for drop-forged high speed tool blanks are more homogeneous structure, lower machine cost, lower scrap losses, time saved in making a tool, elimination of physical defects, and increased production per tool.

The Manufacture of High-Speed Steel in the Electric Furnace. By R. C. McKenna. (In American Electrochemical Society Reprint 31, p. 417-23.) Details of charging, melting, slagging, teeming, forging heat treatment are discussed and the various important points in the electric furnace practice given.

Tool Steels Influence on Progress and Prosperity. (In Raw Material, Vol. 2, p. 54-59.) Describes alloy steels intermediate between carbon and high-speed steels.

The New High-Speed Steel. By L. Aitchison. (In Autocar, Vol. 44, p. 56-7.) History of high speed steel, new formula using molybdenum of Prof. Arnold, costs.

Salvaging High-Speed Steel Scrap. By S. S. Buckley. (In Railway Mechanical Engineer, Vol. 94, p. 290.) Outlines the method of salvaging high speed steel and describes the spark test for testing the scrap.

High-Speed Cast Steel Tools from the Electric Furnace. By S. H. Bannell. (In Iron Age, Vol. 106, p. 1258-9.) Outlines the practice of the U. S. High Speed Steel & Tool Co. in making tools ready for use in any desired shape.

Production of Tool Steel. By F. R. Daniels. (In Machinery, Vol. 27, p. 42-6.) Outlines the processes employed in the steel mill of the Ludlum Steel Co., Watervliet, which manufactures tool and special alloy steels.

Forging of High-Speed Steels. By A. H. Kingsbury. (In Iron Age, Vol. 105, p. 328-9.) Discusses temperature limits, their effects on cracking and gives recommendations for successful results.

Alloy-Steel Development. By J. W. Marshall. (In American Machinist, Vol. 52, p. 817-8.) Outlines the history of the development of high speed steel.

Manufacture of High-Speed Steel in the Electric Furnace. By R. C. McKenna. (In Transactions Amer. Electrochemical Soc., Vol. 37, p. 319-25, discussion 325-8.) A detailed description from the manufacturer's standpoint of the advantages of the electric furnace process over any other way of making high-speed tool steel. Details of charging, melting, slagging, teeming, forging, heat-treatment, etc. are discussed.

Manufacturing High Speed Steel. By R. C. McKenna. (In Iron Trade Review, Vol. 66, p. 148-9.) Manufacture of high speed steel requires the highest degree of skill and knowledge throughout the process. Describes the process of manufacture and precaution that must be taken.

Oberschleische Eisen-Industrie. Chrom, Wolfram and Molybdän enthaltender Schnelldrehstahl mit Zusatz von Kobalt. (Chrome tungsten and molybdenum high-speed tool steel with cobalt as a substitute.) (In Stahl und Eisen, Vol. 40, I p. 128.) German patent 300765, class 18b, Feb. 19, 1916. A considerable portion of the tungsten can be replaced by molybdenum and cobalt.

Schnellasbeitsstahl (High-Speed Steel). By Stahlwerke Rich Lindenberg. (In Stahl und Eisen, Vol. 40 I, p. 327.) German patent 300731, class 18b, Feb. 27, 1916. This steel contains 0.6-1.2 per cent carbon, ½ per cent manganese, 0.1-0.3 silicon, 3-10 per cent chromium, 1-5 per cent cobalt. May also contain 0.15-2.0 per cent vanadium.

Tungstenless Tool Steel. (In Iron Age, Vol. 105, p. 339.) Molybdenum is used instead of tungsten and cobalt and vanadium are added as stabilizers. This steel was invented by Dr. Arnold.

Two Carbon Tool Steels, One Made from Detinned Scrap. (In Iron Age, Vol. 105, p. 1277.) One of these steels was made from Swedish base in a crucible, and the other was made from detinned scrap in an electric furnace. Tests showed but little difference between the two.

1921

American Practice in High-Speed Steel Manufacture. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, Vol. 25, p. 1097-9.) The impressions of a tool steel manufacturer on visiting several plants. Emphasizes the importance of pure raw materials and metallurgical control of all steps in the process.

Drill Steel from Hollow Ingots. By P. A. E. Armstrong. (In Chemical and Metallurgical Engineering, Vol. 24, p. 960-4.) A definite effort to produce hollow drill steel with a decarbonized interior surface by inserting a mild steel tube in the ingot mold, plugging it with stand, casting the steel and subsequently rolling to size.

Constitution of Chromium Tungsten Steels. (In Chemical and Metallurgical En-

gineering, Vol. 24, p. 791-3.) Recent Japanese work throwing light, upon the complex reactions giving self-hardening and red-hardness properties to modern high-speed steels.

Metallurgy of High-Speed Steel. By D. M. Giltinan. (In Transactions American Society for Steel Treating, Vol. 1, p. 716-26.) An account of the development of high-speed steel and some theories of self-hardening.

Electric Furnace Tool Steel Qualities. By W. J. Green and S. S. Green. (In Iron Age, Vol. 108, p. 669-71.) Takes up the vital considerations in practice to insure regularity, role of purity of stock, sample specifications and alloy or reinforced steels.

Features of Electric Tool Steel Practice. By W. J. Green and S. S. Green. (In Iron Age, Vol. 108, p. 1061-4.) Standardized shop practice necessary, large ingots recommended, and top pouring is preferred.

Failure of Metals Through the Action of Internal Stress Irregularities With Special Reference to Tool Steel. By J. N. Greenwood. (In Engineering, Vol. 111, p. 535-7.) Abstr. of paper before Faraday Soc. Takes up the origin and effect of internal stresses, the properties of metals with regard to resistance to failure, and the hardening and tempering of carbon steels.

Manufacture of High-Speed Steel. By Felix Kremp. (In Official Proceedings, Central Ry. Club, Vol. 29, p. 1042-6, discussion, p. 1046-51.)

Recent Work on Chromium Tungsten Steel. (In Chemical and Metallurgical Engineering, Vol. 24, p. 573-5.) Reviews literature on chromium-tungsten steels especially the work of Japanese investigators. Describes methods of magnetic analysis.

Effect of Tungsten Content on the Specific Gravity of High-Speed Steel. By A. S. Townsend. (In Transaction Amer. Soc. Steel Treating, Vol. 2, p. 133-8.) Specific gravity of high speed steel increases with tungsten content.

High-Speed Steel Manufacture in Sheffield. By P. M. Tyler, (In Iron Age, Vol. 107, p. 371-4. Discussion by Hodson, p. 721-2.) Gives present practice, prices, sources of raw material. Wages are lower than in America.

How to Make the Most Out of High-Speed Steel. By A. J. Wilson. (In Transactions Amer. Soc. Steel Treating, Vol. 1, p. 436-40.) Tells of ways in which the life of high speed steel tools was prolonged.

1922

Preparing Tool Steel at the Mill. By A. W. F. Green. (In Transactions Amer. Soc. Steel Treating, Vol. 2, p. 274-87.) Takes up the effects of proper finishing temperatures in the hammer shop and rolling mill on the steel and the normalizing and annealing of the product.

Crucible and Electric Tool Steel. By W. J. Green and S. S. Green. (In Iron Age, Vol. 109, p. 201-5.) Discusses the difference between crucible and electric tool steel, and compares the operating conditions in detail.

HEAT-TREATMENT OF HIGH-SPEED STEEL

1900

Steel for High-Speed Cutting Tools. (In Mechanical Engineering, Vol. 6, p. 685-6.) Editorial concerning the patent specifications of the Taylor-White process.

The **Taylor-White Process of Treating Steel.** (In Mechanical Engineering, Vol. 6, 6. 699-702, No. 17; American Machinist, Vol. 23, p. 1169-70.) Reprint of the British patent 10788 of 1900.

1903

The **New Tool Steel and Its Effect on Machine Shop Methods.** By C. T. King. (In Wisconsin Engineer, Vol. 7, p. 255-61.) Development of tool steel, discovery of high-speed steel, cause of change in steel structure by heat-treatment.

High-Speed Steel. By H. W. Rushmer. (In Iron Trade Review, Vol. 36, p. 50-1, Sept. 24, American Machinist, Vol. 26, p. 1270-81.) Discovery of Taylor-White process, superiority of new steels, annealing, forging and tempering high speed steels.

Zur **Kenntnis der Theorie der Sogenannten Rapid-und Naturhartern Stahle.** By J. Spuller. (In Chem. Zeitung, Vol. 27, p. 165-6.) On the knowledge of the theory of the rapid and self-hardening steels, considers that as the carbon of the iron carbide becomes mobile at about 1000 degrees Cent. it passes out of the iron carbide and forms chrome carbide, tungsten carbide, it playing a most important part in imparting hardness to the steel.

The **Taylor-White Process of Treating Tool Steel.** (In Journal Franklin Institute Vol. 155, p. 127-37, Bulletin, Society Encouragement pour l'Industries Nationale, Vol. 903, p. 293-8.) Report of the committee on the inventions of Maunsel White and F. W. Taylor. Development and application of the process.

1904

High-Speed Tool Steels. By W. Brown. (In American Machinist, Vol. 27, p. 737-8.) Heat treatment of hardening of tools; rate of speed desirable.

Beitrag zur Kenntnis und Theorie des Schnelldrehstahls. By H. Eckardt. (In Stahl und Eisen, Vol. 24, p. 611-3, extract in American Machinist, Vol. 27, p. 1080-1.) Contribution to the knowledge and theory of high-speed steels. Discussion of the properties of the Taylor-White and European steels made after the Taylor-White process. Deals especially with the cutting and high-speed qualities.

The **Development and Use of High-Speed Tool Steel.** By J. M. Gledhill. (In Journal Iron and Steel Inst. pt. 2, p. 127-67, disc. p. 168-82, Engineering Vol. 98, p. 482-3, disc. Engineering, Vol. 78, p. 675, American Machinist, Vol. 27, p. 1696-1700, 1730-4, Vol. 28, p. 46-51, Mechanical Engineering, Vol. 14, p. 734-6, 782-5, 851-3, 890-2, abstr. in Iron Age, Vol. 74, Nov. 10, p. 12-15 in Iron Trade Review, Vol. 37, p. 83-9, Nov. 3. History, composition, effect of combination of iron and carbide with tungsten and chromium, with tungsten, with molybdenum and chromium, molybdenum and tungsten and chromium; influence of each; analyses; heat-treatment, results of tests. 7 plates.

High-Speed Tool Steel. By J. M. Gledhill. Its Manufacture and Use. (In Engineering, Vol. 97, p. 266-7, Mechanical Engineering, Vol. 13, p. 396-8, 444-6, Iron and Coal Trades Review, Vol. 68, p. 1197-1201, American Machinist, Vol. 27, p. 752-5, 788-807, Abstr. in Iron Trade Review, Vol. 37, p. 14-7, April 21.) Paper read before the Coventry Engineering Society, March 4, 1904. Manufacture of crucible steel, process of converting crucible steel into high-speed steel, annealing, forging and hardening the tools, heat treatment of high-speed steel, cutting tests.

High-Speed Tool Steels. (In Machinist Vol. 10, p. 534-5.) Practical suggestions for hardening the new steels.

Contribution a la Theorie des Aciers Rapides. By F. Osmond. (In Revue de Metallurgie Memoirs 1904, p. 348-52.) Contributions to the allotropic theory of high-speed steel.

The Practical Handling of High-Speed Steels. (In Iron Age, Vol. 74, Oct. 6, p. 7-8.) Treatment of high speed tools, heating, hardening, quenching in fish oil, drawing, costs.

Heat Treatment Experiments with Chrome-Vanadium Steel. By H. R. Sankey and J. K. Smith. (In Inst. Mech. Engrs. pt. 3-4, p. 1235-82, disc. 1283-1317, plates 147-59, abstr. and disc. in Engineering, Vol. 95, p. 615-7.) Detailed tests on chrome vanadium spring steel.

Structure of High-Speed Steels. (In Engineering, Vol. 98, p. 90.) Editorial referring to papers of Le Chatelier and Osmond in Bulletin Society Encouragement pour l'Industrie Nationale.

High-Speed for Finishing. By P. Wesley. (In American Machinist, Vol. 27, p. 529-30.) Result of experimenting on use of high-speed steel tool for finishing. Tool was heated till the point burnt off, and cooled in the air blast.

1905

The Types of Structure and the Critical Ranges on Heating and Cooling of High-Speed Tool Steels Under Varying Thermal Conditions. By H. C. H. Carpenter. (In Journal Iron & Steel Inst., 1905, pt. 1, p. 433-73, 4 plates, 7 inserts abstr. Mechanical Engineering, Vol. 15, p. 315-16.) Concludes that the hardening of rapid tool steel involves the widening, splitting, or lowering of the critical ranges of the special alloy element, and the complete suppression of the widened, split, or lowered range by a mild quenching.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil, Vol. 47, p. 105-8.) Tool steels for high speed. Preparation and use in the shops. Composition influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A. W." steel.

Note sur la Trempe de l'Acier. By L. Grenet. (In Bulletin, Soc. Ind. Min., Vol. 4, p. 973-99.) Note on the hardening of steel, p. 987 chrome-tungsten and high-speed steels. Considers that hardening is caused by a transformation in the cooling to a lower temperature and not by the conservation of a stable state formed at a high temperature.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industrielle, Vol. 1905, p. 315-6, 323-4, 338-9, 358-9; Memoirs Soc. Civ. de France pt. 1, p. 919-45.) P. 315, definition, history, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, than transformation point A′; p. 338 composition of high-speed steel, constitution of chromium and of tungsten steels; p. 358-9, transformation points of chrome-tungsten steel an influence of the constituents; p. 368, properties, treatment, results obtained at Manchester and at Birmingham.

A New Hardening Furnace. (In American Machinist. Vol. 28, p. 354-5.) Brayshaw furnace for use in hardening steel. Fig. 4, heating and cooling curve of Seebohm and Dieckstahls N. C. High-speed steel.

1906

Tempering and Cutting Tests of High-Speed Steels. By H. C. H. Carpenter. (In Journal Iron and Steel Institute 1906, pt. 3, p. 377-96, 5 plates, abstr. in Engineering, Vol. 82, p. 300-4, Stahl und Eissen, Vol. 26, p. 1018-9, transl. in Metallurgie, Vol. 3, p. 511-22, abstr. Mechanical Engineering, Vol. 18, p. 164-70.) Report of research to ascertain whether the temperature at which high-speed steels soften can be pushed higher than 700 degrees Cent.

Quaternary Steels. By L. Guillet. (In Journal Iron and Steel Institute pt. 2, p. 1,141, 1 insert.) Research to systematize the use of quaternary steels, or an alloy of iron, carbon and two other added elements.

Process of Hardening High-Speed Steel. (In Mechanical Engineering, Vol. 17, p. 504.) Patented process of S. N. Brayshaw, heating the steel up to a very high temperature, soaking it in a high temperature bath from 900 degrees to 950 degrees C, quenching it in a bath at 100 degrees C.

Die Entwichlung des Schnellarbeitstahles in Deutschland. By O. Tahallner. (In Zeitung des Verein deut. Ing., Vol. 50, p. 1690-7, 1 insert.) The development of high-speed steel in Germany. The introduction of the Taylor-White Process, outline of process, chemical composition of high-speed steel, influence of carbon, chromium tungsten, molybdenum, silicon; new knowledge on the relation between chemical composition and the hardening-effect the high-speed steels in use.

1907

The Theory of High-Speed Tool Steel. By G. Auchy, (In Iron Age, Vol. 80, p. 1818-22.) Conclusions drawn from a comparison of theories of Osmond, Bohler, Le Chatelier, Carpenter, Arnold, Guillet and Taylor.

The Making of High-Speed Steel Tools. By O. M. Becker. (In American Machinist, 30 pt. 1, p. 411.) Discusses forging, kind of furnace, heating for hardening, the oil bath, method of dipping, degree of hardness desired, tempering furnace.

High-Speed Tool Steel. By H. C. H. Carpenter. (In Iron Age, Vol. 79, p. 822-4.) Contribution to the discussion of F. W. Taylor's "On the Art of Cutting Metals" and reprinted from the Proceedings of the American Society of Mechanical Engineers. Includes corrections red hardness, structure of steel, the heat at which tools cut best, other hardening agents than carbon, the action of chromium and tungsten, classification of types cutting tools, and the question of maximum temperature.

The Hardening of High-Speed Steel Taps. By L. Guillet. (In Iron Age, Vol. 80, p. 368.) Process tested and recommended by Wheelock, Lovejoy & Co., with the use of a barium chloride bath in a standard gas hardening furnace.

Tempering High-Speed Steel. By. G. Lindsay. (In Mechanical Engineering, Vol. 19, p. 75.) Abstract of paper before the American Master Blacksmith's Ass'n. describing the use of a lead bath.

Annealing and Hardening High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30, pt. 1, p. 322-3) Recommends annealing in cast iron box, heat to 800 degrees Cent. for at least 5 hours, raise heat to 900 degrees Cent., shut off fire, close door, remove steel after 12 hours.

Annealing High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30,

pt. 2, p. 493.) Five different methods which can be used for annealing high speed steel attempt to disprove statements of Mr. Viall.

Furnaces for Tempering High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30, pt. 1, p. 664-5.) Suggests furnaces most appropriate for small, and larger tool, and for all round work.

Hardening and Tempering High-Speed Steel. By J. Steele. (In American Machinist, Vol. 30, pt. 2, p. 543-4.) Practical discussion of treatment of high-speed steel tool, use of a forge, advice users not to temper high-speed steel, rehardening steel.

High-Speed Steel. Some Experiences in Annealing, Machining and Hardening, 1907. (In American Machinist, Vol. 30, pt. 1, p. 61.) Practical experience of man unfamiliar with methods of treating high speed steel.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E., Vol. 28, p. 31, 279; disc p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie Memoris, Vol. 4, p. 39-65, 108-84, 233-336, 401-66, abstr. In Engineering, Vol. 83, p. 54-5, abstr. In American Machinist, Vol. 30, pt. 42-6, 215-9, 247-51). P. 22-64. Modern high speed tools using high speed steel, chemical composition of tool-steels for high-speed, discovery of high-speed, discovery of high-speed steel, American Machinist extracts those parts of practical shop value.

1908

The Manufacture of High-Speed Steel. By O. M. Becker. (In Cassier's Magazine, Vol. 34, p. 291-9.) Charging of crucible, melting hole, heating and pouring of the melt, molding the ingot, annealing costs.

Possible Methods of Improving Modern High-Speed Turning Tools. By H. C. H Carpenter. (In Transactions Manchester Ass'n. Engrs. p. 1908-9, p. 81-110, disc pt. 111-2, 2 plates.) abstr. in Engineering, Vol. 206, p. 588-9. Composition manufacture, heat treatment of high-speed tools, manufacture of tool steel in electric furnace, welding high-speed to mild steel, summarizes possible improvements in manufacture and composition of high-speed steel.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346-50, 361-3.) Manufacture and use of tools of high-speed steel. Discussion of paper by A. L. Valentine in the American Machinist includes composition of high-speed steels, analyses, tools used in tests, factors which influence the cutting speed, economic results, hardening high-speed steel, determination of the temperature uses of high-speed steel and economics which result from its use.

Hardening High-Speed Steels. By N. Gross. (In Iron Age, Vol. 81, p. 147; Mechanical Engineering Vol. 22, p. 5-7-8.) Rules to follow in heating and quenching high-speed steels, the necessity of proper hardening.

High-Speed Tool Hardening Furnaces. (In Mechanical Engineering, Vol. 21, p. 414-5, 830.) Illustrated description of Brayshaw's patent salt-bath for hardening and patent furnace for high-speed steel.

High-Speed Steel. By H. H. Hill. (In Mechanical Engineering, Vol. 22, p. 213-4; Mech. Wed., Vol. 44, p. 91-2; brief abstr. Iron Age, v. 81, p. 1406; abstr. Mechanical Engineering, Vol. 21, p. 334.) Paper read before the Liverpool Engineering Soc. Deals with the heat treatment or the annealing, hardening and tempering, grinding, finishing.

New High-Speed Steel Heating Furnace. (In Mechanical Engineering, Vol. 21, p. 382.) Brief illustrated description of high-speed steel tool heating furnace of the British Gas Furnace & Tool Co.

Tool Steel. By F. M. Osborn. (In Iron Age, Vol. 82, p. 1612-3) Abstract of pamphlet, a reprint of a paper before the Leeds Ass'n of Engrs. heat treatment after forging and grinding, results in turning tires at the New York Central shops, making of twist drills and milling cutters from high-speed steel.

A Plant for Hardening High-Speed Steels. (In Iron Age, Vol. 82, p. 1216-7.) Crucible gas furnace for the barium chloride bath, preheating furnace, an oil tempering furnace and quenching baths in the plant of Wheelock, Lovejoy & Co., New York.

La Durete a Chaud des Aciers. By Robin. (In Revue de Metallurgie Memoris, Vol. 15, p. 893-908. The hardness of steels when hot. P. 906-8. Study of high-speed steels, cooling curves.

Ueber Dreharbeit und Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin J. Springer Translation of "On the Art of Cutting Metals" reviewed in Zeitung des Ver. deut. Ing., Vol. 52, p. 970.)

Making and Using of High-Speed Steel Tools. By A. L. Valentine. (In American Machinist, Vol. 30, pt. 2, p. 6-9.) Composition of metal, forging, grinding and tempering of lathe tools and milling cutters.

The Treatment of High-Speed Steel. By E. Viall. (In American Machinist, Vol. 31, p. 314-6.) Treatment for Bohler's Styrian, Bohler's-Boreas, Jessop's Ark, Bethlehem self-hardening, Crescent self-hardening, Midvale special, Firth-Sterling Blue Chip, Allen's high-speed and Burgess' No. 5 special.

Annealing High-Speed Steel. By O. M. Becker. (In American Machinist, Vol. 32, p. 660-1, pt.1.) Furnace, quick and slow annealing, appliances for slow cooking, annealing temperatures, coolers left by annealing and electrical annealing.

1909

Annealing High-Speed Steel. By O. M. Becker. (In American Machinist, Vol. 32, p. 660-1.) Furnace, quick and slow annealing, appliances for slow cooling, annealing temperatures, colors left by annealing and electrical annealing.

English Versus American High Speed Steels. By E. T. Clarage. (In American Machinist, Vol. 32, pt. 1 p. 1031-2. Explanation of the hardening of carbon steels, of high-speed steels, and discussion of the progress made by American manufacturers over that of English.

Annealing High-Speed Steel. By W. G. Groocock. (In American Machinist, Vol. 32, pt. 2, p. 810.) Annealing by placing tool in a gas furnace at night raise it to 1400-1500 degrees, let it cool down in the furnace, and take it out about 10 o'clock the following morning, cool enough to handle, and soft enough to cut.

The Newer British High-Speed Steels. (In American Machinist, Vol. 32, pt. 1, p. 586-7.) Directions given by Samuel Osborn & Co. Ltd., for hardening lathe and planer to tools, data as to endurance under cut from tests of J. J. Saville & Co., Ltd., Thomas Nash & Sons, and Spear & Jacksons, Ltd.

A New Steel. (In Engineering, Vol. 86, p. 190; American Machinist, Vol. 32,

pt. 1, p. 337.) New high-speed steel which is hardened in water. Jonas and Culver of the Continental Steel Works experiments leading up to the discovery.

Some Tests of a New High-Speed Steel. (In American Machinist, Vol. 32, p 847-50, pt. 1.) Novo Superior steel in turning and drilling tests working on forged, rolled and cast steel and cast iron. Rules for forging, hardening and grinding.

1910

Development and Use of the New High-Speed Steel. By W. Carter. (In Engineering, Vol. 109, p. 154-5; Mechanical Engineering; Vol. 25, p. 191-3; abstr. in Stahl und Eisen, Vol. 30, p. 543; abstr. in Iron Trade Review, vol. 46, p. 480-3.) Paper before Birmingham Ass'n of Mach. Engrs. Development, composition heat treatment and use of new high-speed steels containing vanadium.

High-Speed Steel. By O. M. Becker. (In N. Y. McGraw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high-speed tools, analyses of high-speed and special steels, reference table for determining cutting speeds.

High-Speed Tool Steel. By W. V. Brandt. (In Iron Age, Vol. 86, p. 1025; Mechanical Engineering, vol. 27, p. 38.) Method of manufacture and heat treatment.

A High-Speed Steel Tempering Furnace. (In Engineering, Vol. 107, p. 152.) Two-chamber gas furnace constructed by Churchill Machine Tool Co. of Manchester, England.

High-Speed Steel and Its Heat Treatment. By W. G. Smith. (In Mechanical Engineering, Vol. 26, p. 537-50.) Abstract of article in "The Armour Engr." history of high-speed steel, influence of carbon, chromium, tungsten, molybdenum, silicon, method of forging tempering, the barium chloride process and quenching.

Trempe des Outils en Acier Rapide. (In Revue Industrielle, p. 408.) Hardening of tools of high-speed steel. Refers to methods mentioned in American Machinist.

1911

Heat Treatment of High-Speed Tools. By C. P. Berg. (In Western Society Engineers Journal, Vol. 15, p. 738-64; Mechanical Engineering, Vol. 27, p. 154-8.) Relation between temperature and life of tools. Experiments to establish a guide as to how rapidly the steel should be heated under the high heat treatment by a heat absorption test, to determine at which degrees of temperature in the heat-treatment, the maximum cutting efficiency occurs for a steel of a certain chemical composition, to give the reasons for the relation found by these tests, and to illustrate the same by photo-micrographs.

The Practical Use of High-Speed Steel. By J. M. Gledhill. (In Mechanical Engineering, vol. 27, p. 762-6.) Composition, role of different metals, melting, annealing, forging, and hardening, grinding, uses of high-speed steels.

Trempe, Recuit, Cementation et Conditions d'Emploi des Aciers. By L. Grenet. Paris, Beranger 495 pp. Tempering, annealing, case-hardening. P. 348-451. Special steels, including high-speed; properties, forging, heat treatment.

Hardening and Tempering Steel. By B. E. Jones, Cassell & Co., New Y. 128 pp. P. 61-5. Heat-treatment of high-speed steel, p. 66-78 treatment of Mushet, "Novo" "Ultissimus", "Blue-chip" high-speed steels.

1912

Annealing High-Speed Steel. (In Machinery, Vol. 19, p. 257.) Packing in air-slaked lime, heated in an annealing oven to 1900 degrees to 50 degrees Fahr. for 9-10 hours, or packed directly in the oven, heat to 1700 degrees 50 degrees Fahr. for two hours.

Structure and Heat Treatment of Tool Steel. By J. V. Emmons. (In Mechanical Engineering, Vol. 29, p. 284-6; Iron Trade Review; Vol. 50, p. 450-2, one plate.) Gives heat treatment for both carbon or tool steel and high speed steel.

The Influence of Heat on Hardened Tool Steels. By E. G. Herbert. (In Journal Iron and Steel Inst., Vol 85, p. 358-78; Engineering, Vol. 93, p. 851-7; disc in Engineering, Vol. 113, p. 364-5; abstr. Iron Age, Vol. 89, p. 1465-8.) Refers especially to the heat generated in the cutting operation. Gives breaking tests, with resulting hardness, toughness and durability temperature curves for two high-speed steels.

Heating High-Speed Steel in a Blacksmith's Forge for Hardening. By F. A. Parsons. (In Machinery, Vol. 18, p. 884-5.) Covering of work with coating of fire clay and salt, and a thin shield of sheet metal, and then using coal forge fire for heating.

1913

Annealing High-Speed Steel. (In Machinery, Vol. 19, p. 431.) Methods given in Machinery, vol. 19, p. 275, disputed, and gives method with annealing chart used by one of the largest high-speed tool steel manufacturers in America.

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, vol. 45, p. 833-42; v. 46, p. 63-76, 194-200, 400-15, 931-42.) P. 883-42. Theory of hardening, factors conducive to cutting speed, development of tool steels and alloys. P. 63-76, processes of manufacture mechanical treatment, machinery and equipment used, p. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers, p. 931-42, machine tool operation at high cutting speeds, inserts.

Tool Steel From a Salesman's Point of View. By C. M. Bigger. (In Iron Age, vol. 91, p. 706-8; Mechanical Engineering, vol. 31, p. 380-2.) P. 707-8, high-speed steel composition and annealing and the influence of vanadium on the cutting speed and durability.

Structure des Aciers et Modifications Accompagnant les Traitments Thermique. By H. De Nolly. (In Bulletin Soc. l'Ind. Min. vol. 4, p. 371-82, 8 plates.) Structure of steels and modifications accompanying the heat treatment. Point of transformation, theory of hardening, use of microscope, dilation curves of a high speed steel, heated to 850 degrees 1050 degrees Cent.

1914

Aciers a Outils. By M. Denis. (In Revue de Metallurgie Memoirs, vol. 11, p. 4-94.) Tool steels. The cutting properties of tool steels following their heat treatment, and the practical utilization of these cutting properties.

Etude sur les Proprietes Generales des Aciers a Outils. By M. Denis. Revue de Metallurgie Memoirs vol. 11, p. 569-669; abstr. in Journal American Soc. Mech. Eng. vol. 36, p. 0164-6.) Investigation into the general properties of tool

steel, discussing the method of tests and heat treatment of various kinds of tool steels, detailed data of the tests, and conclusions from this data.

Note on the Transformation of Steels. By H. DeNolly and L. Veyret. (In Journal Iron and Steel Inst., vol. 90, p. 165-80; Engineering vol. 98, p. 631-2) Discussion of the carbide theory, the allotropic theory, and a theory of the dissociation of the carbide accompanied by the solid solution in the iron, of the carbon liberated by the association, proposed by the authors, and illustrated by curves of critical points of high speed tool steel.

Heat-Treatment of Steel. New York Industrial Press. 278 pp. P. 81-92. Heat treatment of high-speed steel including the Taylor-White process, annealing chart, and table giving kind of steel, method of cutting off unannealed bars, forging heat, directions for annealing, hardening heat, cooling medium, temper and grinding.

Influence du Temps de Chauffage Avant la Trempe sur les Resultats de cette Operations. By A. Portevin. (In Bulletin Soc. d'Encour, vol. 122, p. 206-82.) Influence of the time of reheating after the hardening on the results of this process.

1915

Modern Steels and Their Heat Treatment. By R. R. Abbott. (In Journal Frank-abstr. in Iron Age, vol. 95, p. 790-2.) Changes in structure of carbon and alloy steels, including tool steels by heat-treatment.

The Effect of Chromium and Tungsten Upon the Hardening and Tempering of High-Speed Tool Steel. By C. A. Edwards and H. Kikkawa. (In Journal Iron and Steel Inst., vol. 92, p. 6-30; disc p. 31-46, 3 plates, inset tables; abstr. Engineering, vol. 100, p. 349-52; disc p. 328-30; Engineering, vol. 120 disc p. 313-4, 344; Mechanical Engineering, vol. 36, p. 257-61, Jern-Kontorets Annaler Bihang, vol. 17, p. 103-14.) Influence of initial temperature and importance of secondary heat-treatment.

Manufacture and Uses of Alloy Steels. By H. D. Hibbard. (In U. S. Bureau of Mines Bulletin 100, 77 pp. Extract Mechanical Engineering, vol. 38, p. 4-6, 31-2.) P. 53-67. High-speed steels including manufacture, composition, effect of carbon, chromium, tungsten, molybdenum, cobalt, copper, sulphur and phosphorus in high speed steel, heat-treatment, theory patents and bibliography.

High-Speed Steels. By F. C. A. H. Lantsberry. (In Journal West of Scotland Iron and Steel Inst., vol. 22 p. 101-24; abstr. Iron Age, vol. 96, p. 238-41; Iron Trade Review, vol. 58, p. 487-91; Mechanical Engineering, vol. 36, p. 144-6.) Heat-treatment, theory of hardness, microstructure.

Points on Hardening High-Speed Screw Machine Tools. By R. A. Millholland. (In Iron Age, vol. 98, p. 745; Mechanical Engineering, vol. 36, p. 314.) Removal of decarbonized area to secure a good cutting edge.

1916

The Heat Treatment of Tool Steel. By H. Brearley. (In N. Y. Longmans Green & Co., 223 pp. Reviewed in Engineering, vol. 104, p. 401.) P. 181-210. High-speed steel includes melting difficulties, forging carbide, envelopes, milling cutters, clinking, flaking, cracking, annealing, red-hardness, high heat, quenching, lathe tests, over-heating, tempering, testing, blisters, grinding.

Initial **Temperature and Critical Cooling Velocities of a Chromium Steel.** By C. A. Edwards, J. N. Greenwood and H. K. Kikkawa. (In Journal Iron and Steel Inst. vol. 93, p. 114-40, disc p. 141-53, 2 plates, 4 inserts; abstr. Stahl und Eisen, vol. 36, p. 173-5; Engineering, vol. 101, disc. p. 465-7.) Shows by a discussion of a long series of experiments how sensitive one particular chromium steel is, to very slight variations in treatment.

German **High-Speed Steel.** (In Iron Age, vol. 98, p. 1111, quotations from Elektrotechnische Rundschau.) Composition of high-speed steel for lathe tools, brief outline of hardening process.

Hardening **High-Speed Steel.** (In Iron Trade Review, vol. 59, p. 270-1; also Mechanical Engineering, vol. 38, p. 165.) Directions distributed by the Vanadium-Alloys Steel Co., Pittsburgh.

The **Transformations of Special Steels at High Temperatures.** By K. Honda, K. Tawara and H. Takagi. (In Journal Iron and Steel Inst., vol. 93, p. 224-54, 3 plates.) Investigation on carbon steels, D. S. W. Steel, Ultra Capital Seebohm, New Capital Seebohm, Bohler Super-Rapid Novo, and Becher Diamond Steels.

The **Metallography and Heat Treatment of Iron and Steel.** By A. Sauveur. 2nd. ed. Sauveur & Boylston, Cambridge, Mass. 486 pp. P. 354-63. Chrome-tungsten or high-speed steel microphotographs, critical points, heating and cooling curves, etching.

Tool **Steel Research.** Transactions Manchester Ass'n Engineers, 1915-16, p. 421-5 disc p. 426-371. Abstract of interim report of the Tool Steel Research Committee of tests on ordinary high-speed steel.

1917

Heat-**Treatment of High-Speed Steel Tools.** By A. E. Bellis and T. W. Hardy. (In A. S. M. E. Bulletin 121, p. 61-8.) Iron Trade Review, vol. 60, p. 727-8; Am. Soc. Mech. Eng. Journal, vol. 39, p. 166-7; Iron Age, vol. 99, p. 425; Metallurgical and Chemical Engineering, vol. 16, p. 341-2; disc. A. I. M. E. Bulletin 123, p. 408-15, 124 p. 515-9; Iron Trade Review, vol. 60, p. 728-9; A. I. M. E. Bulletin 126, p. 998-1000. Discussion, table, plates of microphotographs of hardening experiments on five different high-speed tools.

Gas Furnaces, Their Design and Manipulation. By A. Forshaw. (In Engineering, vol. 104, p. 535-537, 589-91. P. 591, furnaces used in the hardening of high-speed steel, two chamber furnace, tool is placed in preheater and heated to redness, then transferred to hot chamber, heated to between 1200 degrees-1300 degrees Cent., then quenched in oil, or in "Feusalt" at a temperature of 230 degrees Cent.

Hardening **High-Speed Steel Tools.** By F. H. Koroff. (In American Machinist, vol. 46, p. 578.) Cyanide process for hardening steel tools with delicate edges.

Hardening **High-Speed Steel.** By J. Thompson. (In American Machinist, vol. 46, p. 344.) Instruction for hardening of high-speed steel cutters of tools of irregular shape and great accuracy.

1918

Pyrometry **Applied to the Hardening of High-Speed Steel.** By J. O. Arnold. (In Transactions Faraday Soc., vol. 13, p. 271-5.) Also Engineering, vol. 104, p. 527. Description of pyrometers in use at Sheffield University, where high-

speed steel is generally hardened from a temperature of 1300 degrees Cent., in a bath of barium chloride fused by the aid of iron electrodes.

Steel and Its Heat Treatment. By D. K. Bullens. 2nd. ed. N. Y. John Wiley & Sons, 483 pp. P. 332-48, chromium steels, p. 349-77, chromium-nickel steels, p. 378-86, vanadium steels, p. 387-402, manganese, silicon, tungsten and molybdenum steels. P. 403-10, high-speed steel including chemical composition, effect of tungsten, effect of chromium, critical ranges, Taylor-White method and American hardening practice.

The Hardening and Tempering of Steel. By C. A. Edwards. (In Transactions Manchester Ass'n of Engrs. 1917-19, p. 229-50, disc. 250-68, 1 plate; abstr. Engineering, vol. 125, p. 161-2; Engineering, vol. 105, p. 267-70.) Hardening and tempering of nickel, chromium, tungsten and high-speed chromium tungsten steels.

High-Speed Steel Hardening Furnace. (In Engineering, vol. 126, p. 319.) Brief description and illustration of furnace introduced by Brayshaw Furnaces Tools Ltd., Manchester.

Iron and Steel. By E. Oberg and F. D. Jones. (In N. Y. Industrial Press, 328 pp.) P. 276-97, High Speed Steel, includes origin, Taylor-White process of heat-treatment, production of high-speed steel, effect of different elements of high-speed steels, hardening practice, tempering, annealing, uses.

How to Treat High-Speed Steel. By J. L. Thorne. (In Iron Age, vol. 102, p. 314.) Abstract of paper on the metallurgical treatment of high-speed steel before the Steel Treating Research Society of Detroit.

Recherches sur l'Acier a Coupe Rapide Faites au Laboratoire du Harvard. By M. Yatesevitch; translated by H. Herbert. (In Revue de Metallurgie Memoirs, vol. 15, p. 55-109, bibliography 109-115.) Research on high-speed steel made at the Laboratory of Harvard. Study on the "Dreadnought" steel of the Halcomb Steel Co. on determination of the modifications in structure and caused by heating and cooling under various conditions, microscopic study of heat-treatment, relation between hardness and heat-treatment.

A Special Tool Steel Heating Furnace. (In Iron Age, vol. 101, p. 553.) Furnace for use with tool of high-speed steel, patented by W. R. Bennett, of the Bennett Metal Treating Co., Elmwood, Conn.

1919

The Hardening of Steel. By H. C. H. Carpenter. (In Engineering, vol. 107, p. 340-1, 386-90.) Paper at the Royal Institution. Theoretical paper attributing hardening to the existence of a hard amorphous constituent in the steels. Refers in the discussion to martensite and to high-speed tool steels.

Manufacture and Use of Alloy Steels. By H. D. Hibbard. J. Wiley & Sons, N. Y. 96 pp. P. 68-87, manufacture, composition, heat-treatment, theory, testing, using and patents of high speed steels. Bibliography.

Heat-Treatment of Chisel Steel. By N. B. Hoffman. (In Journal American Steel Treaters Society, vol. 2, p. 155-60.) Historical review, heat treatment of high-speed for chisel, tests.

The Propertics of High-Speed Steel. By G. J. Horvitz. (In Journal American Steel Treater's Society, vol. 1, p. 324-48; abstr. Iron Age, vol. 103, p. 1711-4.) Composition, crucible and electric processes of manufacture, hardening heat treatment, theory of hardening, physical properties, 13 microphotographs.

A Brief Record of Results of the Annealing of a Chromium Molybdenum and a Chromium Steel. By J. O. Liebig. (In Journal Am. Soc. Steel Treaters, vol. 2. p. 168-71.) Results and microphotographs.

American Practice for Hardening High-Speed Steel. By A. F. McFarland. (In Proceedings Steel Treating Research Society, vol. 2, no. 6, p. 34-6, disc. p. 36, 38, 40, 42, 45-6.) Practice of Bullens, Brearly, Taylor-White, prevention of scale, relation of cutting efficiency to hardness, file tests.

Engineering Machine Tools and Processes. By A. G. Robson. Longmans, Green & Co., N. Y., 307 pp. P. 51-8. Treatment of tool steels and tools including high-speed tool steel treatment, brief discussion of alloys used in high-speed steel, melting of charge, annealing, forging and hardening, grinding, results of use of A. W. high-speed steel.

Heat Treatment of High-Speed Steel. By C. U. Scott. In Journal American Steel Treaters Society, vol. 1, p. 299-301. Practical instructions concerning hardening of high-speed steel.

Electric Welding of High-Speed Steel and Stellite in Tool Manufacture. By P. T. Van Bibber. (In American Machinist, vol. 50, p. 425-32.) Shows a practical way to save an enormous amount of high speed or other steel that is wasted annually. It shows how new tools may be produced so as to use the high-priced steel only for the vital parts.

1920

Some General Principle of Tool Hardening. By A. E. Bellis. (In Journal American Steel Treater's Society, vol. 2, p. 364-6.) Application of the principle of uniformity to the hardening of high speed steel tools.

On the Structural Constitution of High-Speed Steel Containing Chromium and Tungsten and the Effect of These Elements on its Hardening and Tempering. By K. Honda and T. Murakami. (In Science Report of the Tokoku Imperial University, vol. 9, p. 143-68, 7 plates; Journal Iron and Steel Inst. Reprint 15.) Object of research is to ascertain the structural constitution of high-speed steel, the change of these constituents during heating and cooling, and the effect of these constituents upon hardening and tempering.

A Comparative Test Upon High-Speed Steels. By A. J. Langhammer. (In Chemical and Metallurgical Engr., vol. 22, p. 829-32, p. 889-92, 939-42; American Machinist, vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel, stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of maker's recommendations for treating lathe and planer tools, p. 889. Conditions entering into the testing of a tool for cutting as listed by Taylor—are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel. P. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition, heat-treatment and hardness.

Hardening of High-Speed Steel. By A. H. d'Arcambal. (In Railway Mechanical Eng., vol. 94, p. 665-6.) Describes experiments made to determine the effect of various hardening methods on the hardness microstructure and cutting efficiency of high-speed steel.

Temperature Ranges in Hardening Steel. By C. T. Hewitt. (In Iron Age, vol.

106, p. 67-8.) Gives a comparison of scleroscopic results and hardening temperatures, the effect of overheating and enlargement of the grain.

1921

Various Methods for Hardening High-Speed Steel. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, vol. 25, p. 1150-1; also in American Machinist, vol. 56, p. 212-3.) Gives advantages and disadvantages of different methods of hardening high-speed steel that have been proposed in 20 years.

Heating and Quenching High-Speed Steel. By A. E. Bellis. (In Transactions American Society for Steel Treating, Vol. 1, p. 441-45.) Gives reasons and advantages for processes used in heating and quenching high-speed steel

Prevention of Hardening Cracks and the Effect of Controlling Recalescence in a Tool Steel (By. S. N. Brayshaw. (In Journal Iron & Steel and Inst., Vol. 103, p. 131-216, discussion p. 217-49, abstr. in Iron Age, Vol. 107, p. 1400-1.) Describes tests to determine cause of cracks, and methods of prevention.

Heat Treatment of Rock-Drill Steel. By G. H. Gilman. Abstracts 1921. (In Mining and Metallurgy, Vol. 174, p. 35, p. 38-9, Eng. and Contr., Vol. 56, p. 55-6.) Gives practical hints on ways of prolonging the life of rock drill steel and getting better results.

Action of Internal Stress on Tool Steel.. By C. N. Greenwood. (In Forging and Heat Treating, Vol. 7, p. 560-63.)

Hardening of Tungsten Steels. (In Engineering, Vol. 112, p. 517.)

Heat Treating of Tool Steels. By L. A. Lanning. (In Blast Furnace and Steel Plant, Vol. 9, p. 706-7.) Effect of rates of heating, temperatures, and quenching medium upon the dimensions of cylindrical pieces of tool steels.

Note on Double Preheating High-Speed Tools for Hardening. By A. E. MacFarland. 1921. (In Transaction American Society Steel Treating, Vol. 1, p. 306-9.) Discusses decarbonization and the advantages of double preheating.

Theory and Practice in the Drill Sharpening Shop. By J. A. Noyes and V. M. Lee. (In Engineer and Contractor, Vol. 55, p. 387-9.) Gives 15 rules for good practice in treatment of drills.

Oxidation of Carbon Tool Steel on Heating in Air. By H. Scott. (In Chemical and Metallurgical Engineering, Vol. 25, p. 72-4.) Describes experiments made to determine to what extent decarbonization and scaling are likely to alter the structure and dimensions of carbon tool steel under heat treatment.

Relation of High Temperature Treatment of High-Speed Steel to Secondary Hardening and Red Hardness. By H. Scott. (In Transactions American Society for Steel Treating, Vol. 1, p. 511-26. Reprinted from U. S. Bur. Stds., Sci. Paper 395.) An investigation to determine the alloy forms in heat treated high speed steel, and the behavior of the physical properties of the steel.

Heat Treatment of High-Speed Steel. By J. Thorne. (In Transactions American Society for Steel Treating, Vol. 1, p. 727-33.) Takes up the influence of elements on high-speed steel, and the method of heat treating.

Proper Heat Treatment for High-Speed Steel.. By J. L. Thorne. (In Canadian Machinist, Vol. 26, p. 36-7, 53.)

USES AND TESTS OF HIGH-SPEED STEEL

1900

Improvements in Tool Steel. (In Mechanical Engineering, Vol. 6, p. 319-20.) Account of tests by the Bethlehem Steel Co. to show the representatives of the American Technical Journals the behavior of tools made by the new process.

Ueber den Taylor-Whiteschen Werkzeugstahl. By Reuleaux. (Sitz. des Vereins zur Beförderung des Gewerbfleisses, Nov. 5, p. 179-89, abstr. in Glückauf, Vol. 37, p. 236-7.) Taylor-White tool steel as shown at Paris exhibition.

The **Taylor-White Process of Treatment of Steel.** (In American Machinist, Vol. 23, p. 183-4.) Tests of properties of lathe tools made of steel treated by the Taylor-White process and Mushet steel.

Werkzeugstahl der Bethlehem Steel Co. In Zeitung des Ver. deut. Ing., Vol. 46, p. 1666.) Discussion in the "Rundschau" of the cutting speeds and composition of the new steel of the Bethlehem Steel Co.

1901

Acier pour Outils. (Bulletin Society d' Encouragement Ind., p. 539-42.) Steel for tools. Discussion of report of commission of the Association of German engineers.

The **Taylor-White Process of Treating Tool Steel, and Its Influences on the Mechanic Arts.** By C. Day (In Journal Franklin Institute, Vol. 152, p. 161-78; abstr. Engineering, Vol. 72, p. 416; Mechanical Engineering, Vol. 8, p. 574-5; Iron Age, Vol. 68, Sept. 19, p. 10-13. Outline of the Taylor-White process, application at the Link-Belt Engng. Co.'s works.

Versuche mit einem neuen Werkzeugstahl. By E. Heissig. (In Stahl und Eisen, Vol. 21, p. 26.) Experiments with a new tool steel at the works of Böhler & Co. at Wient, Berlin.

Schnelldrehstahl. (In Zeitung des Ver. deut. Ing., Vol. 45, p. 1377-86.) High speed steel, Report of the committee of German Engrs. of the Berlin District O. Lasche, chairman for Feb. 15-July 12, about 250 different steels. Preparation of steels, testing, time curves for blunting the tools, tables giving cutting speeds, and feeds, recording of the tests.

Special Tool Steel. (In Mechanical Engineering, Vol. 8, p. 379-80.) Test of Taylor-White tool steel as compared with Mushet steel. Tests on Speedicut steel of Thos. Firth & Sons, Ltd., Sheffield.

Der **Stahl der Bethlehem Steel Co. und der Taylor-White Process.** By O. Thallner. (In Stahl und Eisen, Vol. 21, p. 169-76, 215-20.) The steel of the Bethlehem Steel Co. and the Taylor-White process. Report of personal investigation of the new process undertaken in the interests of "Bismarckhutte" who intended to acquire the rights for Germany, but as a consequence of the report, desisted.

Das **Wesen des Amerikanischen Schnelldrehstahles und des Taylor-White-Verfahrens und Uber die Ergebnisse mit Deutchen Schnelldrehstahlen.** By O. Thallner. (In Zeitung Des Ver. deut. Ing., Vol. 45, p. 1609-10.) The American high-speed steels, the Taylor-White process and the results with German high-speed steel.

Tool Steel. (In Engineering, Vol. 72, p. 145.) Mention of new steels made by See-

bohm and Diechstahl and tested at works of Sir W. G. Armstrong & Co., to compete with the new American high-speed self-hardening steel.

1902

Acier pour outils. (In Revue Industrielle, 1902, p. 249-50.) Outline of tests and results of the Association of German Engrs. to get the best results with high-speed steel, following the Taylor-White process.

Einige Betrachtungen Uber Schnelldrehstahle. (In Zeitung f. Klein u Strassenhahnwesen. Dec. 16, 1902.) Notes on high-speed steel. Tabulated results of tests of the Bischoff steel at cutting speeds of 16-64 meters per min.

An Improved High-Speed Tool Steel. (In Mechanical Engineering, Vol. 10, p. 773.) Paragraph concerning steel produced by a new process at the Bismark Furnace in Silesia, Germany. Comparative figures of Taylor-White steel and carbon tool steel.

New Tool Steels. By J. W. E. Littledale. (In Transactions Northeast Coast Institution of Engrs. and Shipbuilders, Vol. 18, p. 21-37.) Tests on new rapid steels.

Schnelldrehstahle und deren Anwendung. By O. Mulacek. (In Stahl und Eisen, Vol. 22, p. 454-6, 528-30.) High-speed steel and its use, composition, theory of the hardening of the steel use in cutting, machine, speeds and tests. Paper read before the Mittelthuringer Bezirkverein deutscher Ingenieure.

A New High-Speed Tool Steel. (In Engineering, Vol. 74, p. 190.) Description and tests of Air Novo steel, made by Jonas and Culver of the Continental Steel Works, Sheffield.

The Novo Air Steel. (In Iron Age, Vol. 69, p. 9, May 1.) Tests of a high-speed steel, air hardening or hot water hardening, of Jonas & Culver, Ltd., Sheffield, England.

New Tool Steels and Their Advantages. (In Iron and Coal Trades Review, Vol. 64, p. 1516-8.) Results of tests of new high-speed steels made by Jessop & Sons, Jonas & Culver, the Berlin Section of the Society of German Engrs., Schoeller & Co., followed by outline of Taylor-White process, that data on saving by use of high-speed tools, and data on pressure and feeds to be used.

Nouvel Acier dur pour Outils a Grand Travail. (In Revue Industrielle, p. 348-9.) New hard steel for high-speed tools. Description, table and graph showing power and speed obtained by new "Belmont et Moine" steel marked "Ideal."

1903

American Tests of Rapid Cutting Tool Steels. (In Iron Age, Vol. 72, p. 16-19, Dec. 31.) Tests on high-speed steel by Lodge & Chipley in their shoproom.

"A. W." Rapid Cutting Tool Steel. (In Engineering, Vol. 76, p. 759, Illus. P. 756.) Details of machines used by Mr. Gledhill to test the new high-speed steels.

Schnelldrehbank und Schnelldrehstahl. By F. Bischoff. (In Stahl und Eisen, Vol. 23, p. 132-4.) High-speed lathe and high-speed steel. Use of Bischoff steel in turning other steels.

The Requirements of Machine Tool Operation with Special Reference to the Motor Drive. By C. Day. (In Iron Age, Vol. 71, Jan. 8, p. 16-21; American Machinist Vol. 26, p. 370-2, 404-7, 441-2.) P. 17-18. Tests with steel made by the Taylor-White process of self-hardening. Paper before New York Electrical Society.

High-Speed Tool Steel. (In Mechanical Engineering, Vol. 12, p. 579-80.) Editorial on report of J. T. Nicholson to the Manchester Association of Engrs.

High-Speed Tool Steel. (In Engineering, Vol. 75, p. 81-2.) Particulars of tests made for the purpose of comparing the efficiency of ordinary twist drills with that of twist drills made of high-speed steel at works of Yarrow & Co., Poplar, England.

High-Speed Tool Steel. (In Engineering, Vol. 95, p. 119.) Editorial concerning advantages of use of new steels.

The New Tool Steel and Its Effect on Machine Methods. By C. T. King. (In Wisconsin Engineering, Vol. 7, p. 255-61.) Development of tool steel, discovery or high-speed steel, cause of change in steel structure by heat-treatment.

Schnelldrehstahle. By E. Körting. (In Zeitung des Ver. Deut. Ing., Vol. 47, p. 287.) Brief discussion of experiments on high-speed steel by the Körting firm.

Comparative Trials of High-Speed Steels. By G. Kuwaoi. (In American Machinist, Vol. 26, p. 1230-1) Report of tests of Noro, Speedicut, High-Speed Alpha, and Capital steels.

High-Speed Tool Steel. By W. Lodge. (In Iron Trade Review, Vol. 36, p. 52, May 21.) Advantages to out-put by use of high-speed steel.

High-Speed Cutting Steel. By J. Miley. (In Iron and Coal Trade Review, Vol. 66, p. 299-300; abstr. in Mechanical Engineering, Vol. 11, p. 197-8.) Progress made in the manufacture of high-speed tool steel in the Sheffield district, and the results of its use in English workshops.

Report on Experiments with Rapid-Cutting Steel Tools made at the Manchester Municipal School of Technology under the auspices of a Joint Committee of Members of the Manchester Ass'n. of Engrs. and of Members of the School of Technology Sub-committee, together with Prof. J. T. Nicholson. By J. T. Nicholson. (In Manchester p. 590-5, 636-46, Engineering, Vol. 96, p. 416-7, 419, 473-4, American Machinist, Vol. 26, p. 1620-2, 1658-62, Mechanical Engineering, Vol. 12, p. 586-91, 630-9, 656-61. abstr. in Iron Age, Vol. 72, p. 28-9. Nov. 26.) Arrangements for the experiments, information supplied to the committee by the tool-makers, lathes and other apparatus. Results of tests. 25 tables.

The Inefficiency of the Standard Lathe for High-Speed Cutting. The Maximum Duty of High-Speed Steel. By H. M. Norris. (In American Machinist, Vol. 26, p. 838-40.) Tests of standard lathe with Novo steel.

Rapid-Cutting of Metal—Why Don't It Get Hot? By W. Osborne. (In American Machinist, Vol. 26, p. 531.) Letter asking why high-speed steel does not generate the heat that would be expected from the rate at which it is run.

Rapid Tool Steels. (In Engineering, Vol. 76, p. 255-6; Iron Age, Vol. 72, Sept. 17, p. 42-3.) Discussion of various tests resulting from the exhibition by the Bethlehem Steel Co. of the working capacity of the Taylor-White tools at the Paris Exhibition of 1900; the Berlin Trials, and the theories of Reiser and Spuller.

Notes on High-Speed Tool Steels. By H. H. Suplee. (Inst. Mech. Engrs. Proceedings, pt. 3-4, p. 457-69, disc. 467-81, Engineering, Vol. 476, p. 146-7, abstr. Engineering, Vol. 95, p. 112-3, Mechanical Engineering, Vol. 121, p. 295.) Verified data as to the use of high-speed tool steels in the works of the Union Pacific Railroad at Omaha, Neb.

Tests With High-Speed Tool Steels. (In Mechanical Engineering, Vol. 12, p. 357-8.) Tests of cutting speeds with high speed tool steels on medium steel, wrought iron, and cast iron, by H. H. Vaughan at the Collinwood shops of the Lake Shore & Michigan Southern Railway.

1904

High-Speed Steel Twist Drills and Milling Cutters. By Camell, Laird & Co. (In Engineering, Vol. 98, p. 110.) Letter reporting tests on "0172" high-speed steel, which show great economy in its use, notwithstanding the extra cost.

High-Speed Tool Steel Economies. By Cammell, Laird & Co. (In Iron Age, Vol. 74, p. 21, Aug. 25.) Statement of the costs of drilling with ordinary steel drill, and with a high-speed steel drill.

Machine Tools and High-Speed Steel. By J. A. Carney. (In Iron Age, Vol. 73, p. 16, Jan. 7.) Advantages of reconstructing machine tools to use high-speed steel.

Experiments with Rapid Cutting Tools. By C. Day. (In Transactions Inst. Engrs. and Shipbuilders in Scotland, Vol. 47, p. 170-8, disc. 178-91, abstr. Engineering, Vol. 47, p. 230-232.) Paper based on report of tests made by the Manchester Association of Engrs. and the Manchester City Council.

Considerations sur le Choix D'un Acier a Outils a Grand Rendement. By M. L. Demozay. (In Revue de Metallurgie Memoirs, p. 361-89, 419-57.) Considerations on the choice of a tool steel. Mathematical paper referring to high-speed tool steel tests at Manchester.

Beitrag zur Kenntnis und Theorie des Schnelldrehstahls. By H. Eckardt. (In Stahl und Eisen, Vol. 24, p. 611-3, extract in American Machinist, Vol. 27, p. 1080-1.) Contribution to the knowledge and theory of high-speed steels. Discussion of the properties of the Taylor-White and European steels made after the Taylor-White process. Deals especially with the cutting and high-speed qualities.

The Introduction of High-Speed Steels in Engineering Work Shops. By F. Fielden. (In Engineering, Vol. 77, p. 318-9.) Brief discussion of hardening and grinding of new steels, objections to introduction into work shop, charts and data needed by operators.

The Development and Use of High-Speed Steel. By J. M. Gledhill. (In Journal Iron and Steel Inst., pt. 2, p. 127-67, disc. p. 168-82, Engr. vol. 98, p. 482-3, disc. Engineering, Vol. 78, p. 675, American Machinist, Vol. 27, p. 1696-1700, 1730-4, Vol. 28, p. 46-51, Mechanical Engineering, Vol. 1, p. 734-6, 782-5, 851-3, 890-2, abstr. in Iron Age, Vol. 76, Nov. 10, p. 12-15, in Iron Trade Review, Vol. 37, p. 83-9, Nov. 3.) History, composition, effect of combination of iron and carbide with tungsten and chromium, with tungsten, with molybdenum and chromium, molybdenum and tungsten and chromium; influence of each; analyses; heat-treatment, results of tests. 7 plates.

High-Speed Tool Steel—Its Manufacture and Use. By J. M. Gledhill. (In Engineering, Vol. 97, p. 266-7, Mechanical Engineering, Vol. 13, p. 396-8, 444-6, Iron and Coal Trades Review, Vol. 63, p. 1197-1201, American Machinist, Vol. 27, p. 352-807, abstr. in Iron Trade Review, Vol. 37, p. 44-7, April 21.) Paper read before the Coventry Engineering Society, March 4, 1904. Manufacture of crucible steel, process of converting crucible steel into high-speed steel, annealing, forging and hardening the tools, heat treatment of high speed steel. Cutting tests.

On the Practical Application of the Results of the Manchester Experiments with

Rapid Cutting Tool Steels. By C. F. Hatton. (Published by the author, London, 31 pp.) Abstr. in American Machinist, Vol. 27, p. 538-9.

High-Speed Steel Tests at St. Louis. (In Iron Trade Review, Vol. 37, p. 53, Oct. 20.) Conditions of Test. Results given on p. 62.

High-Speed Steel and the Manufacture of Armor-Piercing Projectiles. (In American Machinist, Vol. 27, p. 877-80.) Use of "Blue Chip" high-speed steel at the Demmler plant of the Firth-Sterling Steel Co. of Pittsburgh, Pa.

High-Speed Steel for Milling Cutters. (In American Machinist, Vol. 27, p. 1149-50. Use of milling cutters of Novo steel by the Cincinnati Milling Machine Co.

High-Speed Tool Steel. (In Engineering, Vol. 78, p. 349.) Tabulated results of tests on twist-drills and milling cutters manufactured from "0172" high-speed tool steel by Cammel, Laird & Co.

Les Aciers Rapides a Outils. By H. Le Chatelier. (In Revue de Metallurgie, Memoirs, 1904, p. 334-47.) Rapid steel for tools, composition, analyses and tests of high-speed steels resulting from exhibition of steels made by Taylor-White process in Paris, 1900.

High-Speed Tool Steel Tests. By Lodge and Shipley Machine Tool Co. (In American Machinist, Vol. 27, p. 10-14.) Report of a series of experiments to determine the relative value of the several high-speed steels, the speed limit it is possible to maintain, and to fix the relative breaking-down point of each grade of steel tested.

Manchester High-Speed Steel Tests. (In Engineering, Vol. 97, p. 142.) Discussion of the reply to Dr. Nicolson on the main points brought forward during the discussion of his report on the series of high-speed steel tests carried out under his supervision at the Manchester School of Technology.

Alloy Steel. By W. Metcalf. (In Proceedings Amer. Soc. Test. Mat., Vol. 4, p. 204-10, disc. p. 211-4, American Machinist, Vol. 27, p. 961-2.) Development and value of high-speed steel. Analyses of two brands.

High-Speed Turning. By J. Miley. (In Engineering, Vol. 97, p. 146.) Abstract of paper before Leeds Ass'n. of Engrs. on progress of British manufacture of high speed steel, and on experiments to show the efficiency of the steel.

Notes on Tests of Rapid-Cutting Steel Tools. By C. Pendlebury. (In Engineering, Vol 97, p. 331-2. Results of tests on speed of cutting, amount of metal removed, power required to remove the metal with special reference to the Manchester trials of the Manchester Association of Engrs.

Profit in the Use of High-Speed Steel Tools. (In Iron Age, Dec. 1, p. 14-5.) Discussion of costs and savings, change in piece rate, etc., caused by the introduction of new steel tools.

Notes on "High-Speed Steel," etc. By J. Vose. (In American Machinist, Vol. 27, p. 586, 588. Use of high-speed steel, lubrication, finishing, change in lathe design.

High-Speed Steel for Finishing. By P. Wesley. (In American Machinist, Vol. 27, p. 529-30.) Results of experiments on use of high-speed steel tool for finishing. Tool was heated till the point burnt off, and cooled in the air blast.

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High-Speed Steel in the Factory. By O. M. Becker and W. Brown. (In Engineer-

ing Magazine, Vol. 29, p. 913-20, Vol. 30, p. 88-98, 241-51, 388-413, Vol. 31, p. 231-46, 397-405, 712-21.) P. 913-20. Advantage of high-speed steel over the older tool steels; p. 88-98, details of introducing machines using high-speed steel in place of those using carbon steels; p. 241-51, making of tools from high-speed steels; 6. 388-413, operation of the tools and of the machines carrying them; p. 234-46, adoptability of alloy steel tools; p. 397-405, the tool at work; p. 712-21, feeds and speeds for the new tool steels.

High-Speed Tool Steels. By L. P. Breckenridge. (In Univ. of Illinois Circular No. 1, of the Engineering Experiment Station. 9 pages.) Properties of tool steels, advantages of high-speed steels. Results of experiments made by Manchester School of Technology, England. By Bohler Bros. & Co. Vienna and Berlin, Union Pacific Railroad Shops, Berlin Section Vereines Deutscher Ingeniere, Bethlehem Steel Co. and Armstrong, Whitworth & Co.

Tests of High-Speed Tool Steels on Cast Iron. By L. P. Breckenridge and H. B. Dirks. University of Illinois Engineering Experiment Station Bulletin No. 2. Abstr. in Mechanical Engineering, Vol. 17, p. 376-7.

Comparative Tests of Common and High-Speed Drills. (In American Machinist, Vol. 28, p. 218-20.) Results of drilling tests at the Works of the Rand Drill Co.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil, Vol. 47, p. 105-8.) Tool steels for high-speed. Preparation and use in the shops. Composition, influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A.W," steel.

The Practical Use and Economy of High-Speed Steel. By J. M. Gledhill. (In Iron and Coal Trades Review, Vol. 71, p. 1690-92; Engineering, Vol. 80, p. 979-801; Iron Trade Review, Vol. 38, Dec. 7, p. 22-8; abstr. American Machinist, Vol. 29, p. 270-2, Mechanical Engineering, Vol. 16, p. 779-81.) Abstr. of paper read before the Gladgow and West of Scotland Foremen Engr. of Ironworkers Ass'n. Actual practice with high-speed steel for cutting.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industrielle, Vol. 1905, p. 315-6, 323-4, 338-9, 358-9; Memoirs Soc. Civ. de France, pt. 1, p. 919-45.) P. 315. Definition, History, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, than transformation point A'; p. 338, composition of high-speed steel, constitution of chromium and of tungsten steel; p. 358-9, transformation points of chrome tungsten steel of an influence of the constituents; p. 368, properties, treatment, results obtained at Manchester and at Birmingham.

Sind de Schnelldrehspane ebenso Aufgebaut wie die mit den Alten Messern Genommenen? By M. Kurrein. (In Oesterr. Wochenschr f. d. Oeffent Baudienst, Sept. 16, 1905.) Is the constitution of chips from high speed steel the same as from the older cutting steels?

High-Speed Steels. By W. Lodge. (In Iron Age, Vol. 73, p. 697, April 7; Iron Trade Review, Vol. 27, p. 101-3, April 7.) Changes in machine tool design caused by acceleration of pace.

High-Speed Tool Steel and the Lathes for Its Use. By T. J. Nicholson. (In Engineering, Vol. 99, p. 169.) Brief abstract of paper read before the Leeds Univ. Eng'ng. Soc. paper mostly with the force exercised during the operation of cutting.

Tests of High-Speed Tool Steels. (In American Machinist, Vol. 15, p. 49.) Report of tests at the St. Louis Exhibition, but three steels competing.

Tests of Tools of High-Speed Steel. (In Engineering, Vol. 99, p. 200.) Abstract of report of the Committee of Judges at the International Exhibition at St. Louis on tests on high-speed steel. Tabulated results of tests on McInnis, Allen, and Victoria steels.

The Uses of High-Speed Steel. (In Machinery, Vol. 11, p. 420-1.) Questions arising on the introduction of high-speed steel into the shop.

1906

Les Aciers Rapide. (In Revue Industrielle, p. 177.) Rapid steels, refers to tests of Withworth at the exposition of Liege on A. W. steel, and the examples mentioned by Gledhill in the Amer. Machinist.

Tempering and Cutting Tests of High-Speed Steels. By H. C. H. Carpenter. (In Journal Iron & Steel Institute, 1906, pt. 3, p. 377-96, 5 plates abstr. in Engineering, Vol. 82, p. 300-4, Stahl und Eisen, Vol. 26, p. 1018-9, transl. in Metallurgie, Vol. 3, p. 511-22, abstr. Mechanical Engineering, Vol. 18, p. 164-70.) Report of research to ascertain whether the temperature at which high-speed steels soften can be pushed higher than 700 degrees Cent.

High-Speed Steel. By E. Childe, and W. T. Sears. (In American Machinist, Vol. 29, p. 67-8.) Abstr. of papers before the Boston Branch of the National Metal Trades Ass'n. on use of high-speed steel, costs, and records of milling cutters.

L'emploi Pratique des Outils an Acier Rapide. (In Revue Industrielle, p. 387.) Editorial on the practical uses of tools of high-speed steel, referring to series in Engineering Magazine by Becker.

High-Speed Tool Steel Tests. (In Engineering, Vol. 82, p. 67-8.) Discussion of tests on eight brands of high-speed steel by Prof. L. P. Brenckenridge and Mr. H. B. Dirks of the University of Illinois.

1907

Notes on the Manufacture and Upkeep of Milling Cutters. By H. T. Ashton. (In Inst. Mech. Engrs. pt. 3-4, p. 1021-9; ast. in Mechanical Engineering, Vol. 20, p. 903-6; disc. p. 1030-66 plates 83-6; Iron Age, Vol. 81, p. 953; Engineering, Vol. 84, p. 870-4.) Discussion of difficulties of extending the use of high-speed steel to milling cutters of complicated shape, required when cutting to give an accurate finish and a good surface.

A Comparison of the Production Values of High-Speed Tool Steels and Carbon Steels. By G. Bilhab. (In American Machinist, Vol. 30, pt. 2, p. 893-5.) Considers the introduction of the use of high-speed steel tools into the shop, the use in combination with high powered machine tools, costs and savings.

An Analysis of the Evolution of Modern Tool Steel. By H. C. H. Carpenter. (In Engineering, Vol. 83, p. 569-71, 633-4.) Current theories of hardening the wear of tools in cutting metals, epochs in the history of tool-steels, possible future developments. Refers especially to F. W. Taylor's work on the "Art of Cutting Metals."

High-Speed Tool Steel. By H. C. H. Carpenter. (In Iron Age, Vol. 79, p. 822-4.) Contribution to the discussion of F. W. Taylor's "On the Art of Cutting Metals" and reprinted from the proceedings of the A. S. M. E. Includes cor-

rections red hardness, structure of steel, the heat at which tools cut best, other hardening agents than carbon, the action of chromium and tungsten, classification of types cutting tools, and the question of maximum temperature.

Actual Results with High-Speed Steel. By F. H. Colvin.(In American Machinist, Vol. 30, pt. 2, p. 708-9.) Information obtained from shops using steel in various ways, including annealing, speeds on low-carbon steels, handling of high-speed steels, and the question of saving by the use of high speed steel.

Aciers Chrome-Tungsten. By L. Guillet. (In Revue de Metallurgie Memories, Vol. 4, p. 5-24.) Chrome-tungsten steels. p. 1920. Use of chrome-tungsten steel as steel for high-speed cutting.

Machine-Tool Design as Affected by the Use of High-Speed Cutting Tools. By J. T. Nicholson. (Engineering, Vol. 83, p. 870-1.) Changes in design of the lathe.

High-Speed Steel Tools. By E. R. Norris. (In Electrical Journal, Vol. 4, p. 246-58.) The making of the tool, the life of the tool, shape of the tool, application of high speed tools. Refers to F. W. Taylor's "On the Art of Cutting Metals."

Service List of High-Speed Tool Steels. (In Mechanical Engineering, Vol. 20, p. 445-7.) Method of keeping records; tabulated results.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E., Vol. 28, p. 31-279; disc. p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie Memoirs, Vol. 4, p. 39-65, 108-84, 233-336, 401-66. Abstr. in Engineering Vol. 83, p. 54-5, abstr. in American Machinist, Vol. 30, pt. 42-6, 215-9, 247-51.) P. 222-64. Modern high-speed tools using high-speed steel, chemical composition of tool steels for high-speed, discovery of high-speed steel, Amer. Mach. extracts those parts of practical shop value.

Taylor's Untersuchungen Uber Rationelle Dreharbeit. By A. Wallichs, A. and O. Peterson. (In Stahl und Eisen, Vol. 27, p. 1053-62, 1085-92.) Taylor's research on rational lathe work. Detailed discussion of the Taylor's "On the Art of Cutting Metals."

1908

Comparisons of Carbon and High-Speed Drills. (In American Machinist, Vol. 31, pt. 2, p. 709-10.) Averages show that the high-speed steel drills drilled 57 times as many holes as the carbon drills.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346, 849-50, 361-3.) Manufacture and use of tools of high-speed steel. Discussion of paper by A. L. Valentine in the Amer. Mach. includes composition of high-speed steels, analyses, tools used in tests, factors which influence the cutting speed, economic results, hardening high-speed steel, determination of the temperature, uses of high-speed steel and economics which result from its use.

Tool Steel. By F. M. Osborn. (In Iron Age, Vol. 82, p. 1612-3.) Abstract of pamphlet, a reprint of a paper before the Leeds Ass'n. of Engrs. heat-treatment after forging and grinding, results in turning tires at the New York Central Shops, making of twist drill and milling cutters from high-speed steel.

Die Neuesten Erfahrungen mit Schnelldrehstahl. By F. Ruppert. (In Zeit. des Ing., Vol. 52, p. 1611-2.) Paper on the latest practice with high-speed steel read before the Bezirksverein, chemical section, abstracted, and the discussion over

paper. Refers to Wallichs translation of Taylor's "On the Art of Cutting Metals."

Ueber Dreharbeit and Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin. J. Springer. Translation of "On the Art of Cutting Metals" reviewed in Zeit. des Ver deut. Ing., Vol. 52, p. 970.)

1909

Range of Utility of High-Speed Steel. By O. M. Becker. (In Iron Trade Review, Vol. 45, p. 4, 462-5, 507-11.) Most suitable conditions for use, use on castings, cost of tool maintenance use on reciprocating machines, milling machines and rotary planers, drills, files and small tools, in sawing and splitting, in punch work, press work, finishing and wood-working.

A Test of Novo and Novo Superior Steels. By M. I. Francis. (In American Machinist, Vol. 32, pt. 1, p. 822-29.) Testing cutting speeds, durability, tool angles on with the assistance of Mr. Winder, the inventor of Novo Superior.

A Tool Steel Testing Machine and Results. By F. G. Herbert. (In American Machinist, Vol. 32, pt. 1, p.822-29.) Testing cutting speeds, durability, tool angles, wear resistance and hardness of high-speed and carbon tool steels with a turning tool. Includes equal wear speed curves, duty curves.

High-Speed Tool Steels. (In Engineering, Vol. 107, p. 289, 347; American Machinist Vol. 32, pt. 1, p. 728-30.) Tests at Seebohm and Diechstahl's, at Edgard & Allen Co.'s, at Samuel Osborn & Co.'s, at Saville & Co., and at Nash's Test House.

Observation on the Making of High Speed Steel Tools. By O. M. Becker. (In Machinery, Vol. 16, p. 5-7.) Kind of data to preserve, hardness or temper of high speed tools, allowances to be made for variations in sizes of tools after hardening, methods of uniting high-speed steel to the tool body cutting high-speed steel, detecting cracks in high-speed steel tools, and reforging.

The **Newer British High-Speed Steels.** (In American Machinist, Vol 32, pt. 1, p. 586-7.) Directions given by Samuel Osborn & Co., Ltd., for hardening lathe and planer to tools, data as to endurance under cut from tests of J. J. Saville & Co., Ltd., Thomas Nash & Sons, and Spear & Jacksons, Ltd.

Some Tests of Jessop Ark High-Speed Steel. (In American Machinist, Vol. 32, Pt. 1, p. 790.) Tests conducted by the Otis Steel Co. on "Ark" high-speed steel in tools one and one-half x 3 inches, and on a Niles-Bement-Pond Co.'s tire lathe.

Some Tests of a New High-Speed Steel. (In American Machinist, Vol. 32, p. 847-50, pt. 1.) Novo Superior steel in turning and drilling tests working on forged, rolled and cast steel and cast iron. Rules for forging, hardening and grinding.

Some Good Results Obtained by Adding Vanadium to Steel. (In American Machinist, Vol. 32, pt. 1, p. 390-1.) High-speed steel tools containing vanadium machined 87 axles with one grinding, while high speed steel tool which did not contain vanadium averaged 27 axles in tests at Howard Axle Works, Homestead, Pa.

1910

High-Speed Steel. By O. M. Becker. (In N. Y. M'Graw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high-speed tools, analyses of high speed and special steels, reference table for determining cutting speeds.

Unusual Results Obtained by the Use of High-Speed Steel. By C. Berg. (In American Machinist, Vol. 33, p. 676-8.) A series of tests to determine its exact cutting capabilities at the Chicago Works of the Link-Belt Co.

High-Speed Tools and Machines to Fit Them. By H. L. Brackenbury. (In Transactions Amer. Soc. Mech. Eng., Vol. 32, p. 729-51; disc. p. 771-805; Proceedings Inst. Mech. Eng. 1910, pt. 3-4, p. 929-55; disc. p. 986-1026; Mechanical Engineering, Vol. 26, p. 207-9, 216-21; abstr. Engineering, Vol. 90, p. 173-9; Iron and Coal Trades Review, Vol. 81, p. 159-60; Iron Trade Review, Vol. 47, p. 367-71.) Use of high-speed steel, detailed discussion of design and tests of machines using high-speed steel.

Etude sur les Machines Pour Aciers a Coupe Rapide. In Revue Industrielle, p. 343-6.) Study on machines for high-speed steels. Review of the use of "rapid" steel properties of high-speed steels, different kinds of steels, power necessary to cut the metal, influence of the cutting speed, cutting angle, use of high speed steel on old machines, power of modern machine tools.

The Cutting Properties of Tool Steel. By H. G. Herbert. (In Journal Iron and Steel Inst., No. 1, p. 206-42, disc. 243-5, 2 inserts, Engineering, Vol. 89, p. 691-6 extract Revue de Metallurgie, Vol. 7, p. 691-8.) Method of testing tool steel, comparison of carbon and high-speed steels, curves showing results of tests.

The Testing of Lathe Tools. By Ripper. (In Engineering, Vol. 90, p. 356-7.) Paper read at meeting of the British Association. Method of testing, durability tests of high speed steels, and speed-increment tests.

Report on the Wear of Steels and Their Resistance to Crushing. By F. Robin. (In Iron and Steel Inst. Carnegie Scholarship Memoirs, Vol. 2, p. 1-270.) P. 167. Interstrain in high-speed steels.

Tool Steels. (In Engineering, Vol. 109, p. 519-20.) Editorial calling attention to, and discussing paper of E. G. Herbert on the cutting properties of tool steels presented to Iron and Steel Institute (Journal No. 1, p. 206-42.)

1911

The Practical Use of High-Speed Tool Steel. By J. M. Gledhill. (In Mech. Engr., Vol. 27, p. 762-6.) Composition, role of different metals, melting, annealing, forging and hardening, grinding, uses of high-speed steels.

High-Speed Steel Drill Tests. By E. R. Norris. (In American Machinist, Vol. 34 pt. 1, p. 719-23.) Comparative tests at Westinghouse Co. of twisted milled fluted and forged fluted high-speed steel drills. Tungsten content does not seem to influence the efficiency in proportion to its amount.

Die Schule des Werkzeugmachers. By F. Schon. (In Hanover. M. Janecke 156 pp.) Test-book for tool-makers, p. 120-33, high-speed steel, the influence of rapid steels on the construction of tools and machines, grinding of high-speed steel tools.

Super-Vitrite High Speed Steel. (In Iron Age, Vol. 87, pt. 1, p. 282.) Performance of Super-Vitrite high-speed steel in turning shaft in the shops of Howell & Co., Wincobank, Sheffield, England.

L'emploi des Aciers Rapides et Machines—Outils a Grand Rendement. (In Revue Industrielle, p. 176.) The use of rapid steels and machine tools at great speed. Advantage of use of high-speed steel on some machines.

1912

Rolling High-Speed Tool Steel. (In Iron Age, Vol. 90, p. 67-70.) Description of electrically driven mill of the Vanadium-Alloys Steel Co., at Latrobe, Pa. Curves of the power requirements for rolling various sections.

Steels for Taps, Drills and Milling Cutters. (In Machinery, Vol. 19, p. 181-2.) High speed steels recommended for drills and milling cutters.

Vanadium in High-Speed Steel. (In Machinery, Vol. 18, p. 837.) Effect on varying amounts of vanadium from 0.2-1.0 per cent on cutting speed of high speed steel, figures given out by American Vanadium Co.

Recent Advances in Scientific Steel Metallurgy. By J. O. Arnold. (In Engineering, Vol. 95, p. 162, Mechanical Engineering, Vol. 31, p. 153-4.) Paper read before the Royal Institution, traces the development of Mushet high-speed and vanadium high-speed steels. Table gives comparative cutting powers of Huntsman's low-grade and high-grade high-speed steels.

1913

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, Vol. 45, p. 833-42; vol. 46, p. 63-75, 194-200, 400-15, 931-42.) P. 883-42, theory of hardening factors conducive to cutting speed development of tool steels and alloys. P. 63-76, processes of manufacture, mechanical treatment, machinery and equipment used. P. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers, p. 931-42, machine tool operation at high cutting speeds, inserts.

Tool Steel From a Salesman's Point of View. By C. M. Bigger (In Iron Age, Vol. 91, p. 706-8; Mechanical Engineering, Vol. 31, p. 380-2.) P. 707-8, high-speed steel composition and annealing and the influence of vanadium on the cutting speed and durability.

Elecobalto en los Aceros Rapidos. (In Revista Minera, Vol. 64, p. 541-2.) Cobalt in rapid steels. Brief discussion of tests made at Technical High School at Berlin.

Cutting Power of Lathe Turning Tools. By W. Ripper and G. W. Burley. (In Inst. Engrs., pt. 3-4, 1067-1141, disc. 1142-1210; Engng., Vol. 96, p. 737-56.) Tests of carbon steel and high speed steel tools, to determine the way in which the output is effected by the speed of cutting, the depth of the cut, the feed of the tool per revolution of the work, the shape of the nose of the tool, and the physical properties of the metal upon which the cutting tool is acting.

Die Fortschritte deutscher Stahlwerke bei der Herstellung hochlegierter Schneellarbeitsstahle. By G. Schlesinger. (In Stahl und Eisen, Vol. 33, p. 929-39; abstr. in Iron Age, Vol. 92, p. 33.) The progress in German steel works of the production of high alloyed rapid working steels, considering especially the effect of cobalt. Tests on cobalt high-speed tool steel at Royal Technical High School, Berlin.

1914

Aciers a Outils. By M. Denis. (In Rev. de Met. Mem., vol. 11, p. 4-94.) Tool steels. The cutting properties of tool steels following their heat treatment, and the practical utilization of these cutting properties.

Uber die Warmevorgange beim Spanschneidern und die vorteilhaften Schnitt-

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La Taille Economique des Metaux par les Aciers a Coupe Rapide d'apres les Experiences de M. F. W. Taylor. By P. Massot. (In Rev. de M. et. Mem. vol. 11, p. 433-62.) The economic cutting of metals by high-speed steel according to the experiences as of F. W. Taylor.

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Progress in Machine Shop Methods. By E. R. Norris. (In Mech. Eng., vol. 36, p. 403-5.) Development of high-speed steel, use heat-treatment, introduction of stellite. Fig. 1-2 charts showing results of tests of twenty brands of high-speed steel. Paper presented before the International Engng. Congress.

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Note on the Relations Between the Cutting Efficiencies of Tool Steels and their Brinell or Scleroscope Hardness. By J. O. Arnold. (In Journal Iron & Steel Inst., vol. 93, p. 102-4, disc. p. 105-13; extract in Iron Age, vol. 97, p. 1207; Engineering, vol. 103 pp. 450-1, disc. p. 442-3; Engineering, vol. 121, p. 397-8.) No relation between Brinell hardness and lathe efficiency, table of efficiency and hardness of certain high-speed steels.

The Grinding of High-Speed Steels. By C. E. Gillett. (From "Grits and Grinds" Norton Co. in Iron Trade Review, vol. 59, p. 679-81; Mechanical Engineering, vol. 38, p. 340.) Explains causes of grinding difficulties and suggests types of wheels to use.

Tool Steel Research. Trans. Manchester Ass'n. Engrs. 1915-16, p. 421-5, disc. p. 426-371. Abstract of interim report of the Tool Steel Research Committee of tests on ordinary high-speed steels.

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Quelques observations sur "Le Stellite." By L. Guillet and H. Godfroid. (In Revue de Metallurgie, vol. 15, p. 339-46, abstr. in Iron Age, vol. 102, p. 1584-5.) Some observations on stellite including comparison made of the variation in hardness at different temperatures of stellite and a superior quality of high-speed steel.

The **New Cobalt Tool Steel.** (In Iron Age, vol. 91, p. 1477.) Mention of a detailed report of extensive comparative tests of the new German cobalt steel with other tool steels, sent out by the Becker Steel Co. of America.

1919

The **Molecular Constituents of High-Speed Tool Steels and Their Correlations With Lathe Efficiencies.** By J. W. Arnold and F. Ibbotson. (In Journal of Iron & Steel Inst., vol. 99, p. 407-28, disc. p. 429-35, 2 plates, 1 insert, abstr. in Iron Trade Review, vol. 64, p. 1419 to 1421.) The chemical constitutions of high-speed steels, correlation of the chemical of and micrographic analyses with lathe efficiencies of the series. Note on surface tension effects in high-speed steels by F. C. Thompson.

Comparison of a Cobalt-Chrome with a Tungsten Steel. By W. J. Baxter. (In Amer. Soc. Test Mat., vol. 19, p. 161-174, Iron Age, vol. 104, p. 23.) Discussion of Dr. Mathen's paper. Results of comparative tests using cobalterom by the U. S. Navy.

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Results of Practice at Nicetown. By G. D. Kelly. (In Amer. Soc. Test Mat. vol. 19, p. 157-9; Iron Age, vol. 104, p. 22-3.) Discussion of Dr. Mathen's paper including cutting tests, advantages of tungsten content, sweating operation.

Practical Information Concerning High-Speed Steel Abstracts. By R. C. McKenna. (In Ry. Mech. Eng., vol. 93, p. 667-8, Am. Mach., vol. 51, p. 989-91, Iron Trade Review, vol. 66, p. 148-9.) Gives composition, injurious impurities, hardening and trade practice.

Durability of High-Speed Steels. By R. Poliakoff. (In Iron Age, vol. 103, p. 295-6.) Cutting tests in nine brands of high-speed steel chemical composition, results of tests compared with Taylor's conclusions.

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Schnittdruck, Schnittgeschwindigkeit, Vorschub and Lebensdauer bei Gewindefrasern aus Schnellstahl. By H. Ederheimer. (In Zeitung des Ver. Deut. Ing., vol. 64, p. 149-53, transl. in Eng. and Ind. Min., vol. 3, p. 309-11.) Cutting pressure, cutting speeds, feed and life of high-speed steel screw thread milling cutters. Results of tests showing the influence of cutting feed and speed of high-speed screw milling cutters of 38.5, 48, and 53 min. diameter upon the number of cuts possible before the first regrinding is necessary, and upon the total life of the cutter. Life decreases parsbolically with increasing cutting pressure.

A **Comparative Test Upon High-Speed Steels.** By A. J. Langhammer. (In Chemical and Metallurgical Engineering, vol. 22, p. 829-32, p. 889-92, 939-42; Amer-

ican Machinist, vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of maker's recommendations for treating lathe and planes tools. P. 889. Conditions entering into the testing of a tool for cutting as listed by Taylor are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel, p. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition heat-treatments and hardness.

Characteristics Treatment and Uses of High-Speed Tool Steel. (In American Machinist, vol. 53, p. 121-3.) Development of high-speed tool steels, chemical composition, special features, hardening, heat treatment and substitutes.

High-Speed Steel Tools for Turning Tires. By F. A. Stanley. (In Amer. Mach., vol. 53, p. 265-6.) Describes the tools used in the Southern Pacific shops at Sacramento for turning tires.

Tentative Specifications for Carbon Tool Steel. (In Proceedings Amer. Soc. Test. Mat., vol. 20, pt. 1, p. 502-3.) Steel to be made by crucible or electric process (except grade C), must have certain chemical composition, will be analyzed according to standard methods of analysis of plain carbon steel, permissible variations in dimensions are to be agreed upon by contractor and purchaser.

1921

Hardness of High-Speed Steel. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, vol. 25, p. 1168-73.) Hardness of high-speed steel at moderate temperatures, hardness in the cold after various heat treatments, and cutting efficiency are determined to predetermine the usefulness of a modern machine tool.

Standardizing Specifications for Tool Steel. By C. M. Brown. (In Transactions Am. Soc. Steel Treating, vol. 1, p. 666-72.) Discusses the different types of tool steels in use and suggests seven classes for standardization purposes.

Application of Magnetic Analysis to Rock Drills. By C. W. Burrows. (In Mining and Metallurgical Engineering, vol. 174, p. 42-3.) The magnetic test indicates fatigue in the material, shows the location of the fatigue and will indicate whether reclaimation is possible.

Testing of High-Speed Tools. By Thomas Fish. (In American Machinist, vol. 54, p. 466.) Points out the necessity for standard methods of heat treating and testing of high-speed steels.

Analysis of Some Drill-Steel Tests. By F. B. Foley. (In Mining and Metallurgical Engineering, vol. 174, p. 43, 46-7.) Discusses some causes of failure of drill steel.

Metallography of High-Speed Steel. By J. P. Gill and L. D. Bowman. (In Transactions Amer. Soc. Steel Treating, vol. 2, p. 184-205.) Gives heating and cooling curves of high-speed steel, discusses the formation of compounds.

Beitrag zur Frage der Warmformgebung schwerer Blocke aus Schnellarbeitsstahl. By W. Oertel. (In Stahl und Eisen, vol. 41, p. 1413-16.) Hot working of heavy ingots of high-speed steel.

Breakage and Heat Treatment of Rock Drill Steel. By A. E. Perkins. (In Iron Age, vol. 108, p. 7-8.) Gives effect on breakage, maximum and minimum life expected and a comparison with eye bars.

High Carbon Open-Hearth Steel Versus Crucible Tool Steel in the Manufacture of Miscellaneous Tools. By G. Porteous. (In Trans. Amer. Soc. Steel Treating, vol. 1, p. 238-44.) "Just as good results can be obtained by the judicious use of open-hearth high carbon steel with proper heat treatment as can be secured from the use of a higher grade and more expensive tool steel."

When You Have Trouble With the Tool Steel You Are Using. By G. A. Richardson. (In American Machinist, vol. 54, p. 269-70.) Gives the causes that would have a bearing on the performance of tool steels in general.

Steel for Machine Tool Parts. By R. M. Taylor. (In Machinery, vol. 27, p. 770-1.) Gives tables showing physical properties, chemical composition and heat treatment of steels for machine tool parts.

Selection High-Speed Steel for Tools. By H. Traphagen. (In Transactions Amer. Soc. for Steel Treating, vol. 1, p. 527-31.) On the suitability of fracture, hardness chemical and mechanical tests for the selection of high-speed tool steel.

1922

Physical Tests on High-Speed Steels. By A. H. d'Arcambal. (In Transactions Amer. Soc. Steel Treating, vol. 2, p. 586-601.) Takes up transverse stress tests and tensile tests on 18 per cent tungsten, 1 per cent vanadium and 14 per cent tungsten, 2 per cent vanadium grades of high-speed steel.

Extent of Search

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TOOL STEEL MANIPULATION

By L. K. Marshall

IN PRESENTING this paper, under the above title, the aim will be to enumerate some of the most important points encountered in the actual practice of what may be termed scientific heat treatment of tool steel. It is the author's belief that such treatment becomes scientific when all tools, dies, etc., made in one plant are treated under the direct supervision of one head, using apparatus permitting close temperature and time control, both in the hardening and tempering operations; keeping accurate records of each piece handled, and checking up the actual performance of all tools of major importance, all of which leads to duplication of results.

Just as specialization in the tool room is fast replacing the old method of one man performing all operations incidental to the making of a tool or die; so is the method of segregated heat treatment of tool steel bound to replace the less satisfactory system of each man heat treating his own parts and pieces.

Let us follow through such a method. All pieces made in the tool room that call for heat treatment are delivered to a central point together with a delivery ticket which gives all necessary information to positively identify each piece. Each job as it is received is given a test number which is stamped on the piece or pieces where size and design permits. All pertinent information is entered on a report sheet which is made in duplicate. The report form includes data on the number of pieces to be heat treated, the material specification of the pieces, the annealing temperatures used and the method of cooling, the quenching temperatures used and the medium in which the pieces were quenched. The Brinell hardness, the scleroscope hardness and special notations are likewise included in this report form. A blank space on the right side of the form is used for making a free hand sketch of the part or parts. This idea of having a sketch as part of the report has proved its worth time and again. Inasmuch as every piece of tool steel that is to be treated is a problem in itself, each piece as received is studied and its treatment determined before it enters the furnace. It is at this stage that the hardener is confronted with his most serious work, as he now has in his hands the work of days, and oft times of weeks, which he must bring safely through the subsequent heating and quenching operations; and he must also see that the necessary mechanical characteristics, such as hardness, toughness, surface condition, etc., are as desired.

Just picture some of the problems in this connection. How numerous are the previous treatments and workings to which the steel has been subjected, over which the hardener has absolutely no control. From the time the molten steel is poured into the ingot mold, to the time it is made into a finished piece ready for heat treatment, many things may have happened to determine its behavior in the hands of the hardener. Such points as, the amount of ingot that was cropped, the amount of reduction from the ingot to the finished bar, the forging and rolling temperatures, the thoroughness of the annealing operations on the finished stock, are all beyond his control, and yet they all have a direct bearing on the finished tool as it is ready for hardening.

Each piece as it leaves the tool room is stamped with the trade name of

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A paper presented before the Indianapolis Convention. The author, L. K Marshall, is metallurgist, North East Electric Co., Rochester, N. Y.

the steel of which it is made. This marking is checked against the tool drawing to note whether or not a type of steel other than that called for has been used. If a change has been made the reason is traced out before any further work is done. All pieces of major importance are touched on the emery wheel to make positive that the type of steel is as it is marked. This spark test is very important, and has at times saved much time and money by showing that a piece was oil hardening when it was marked as a water hardening steel, which if quenched as marked would obviously have resulted in damage to the piece. Every man who handles tool steel should familiarize himself with the characteristic sparks of the steels he come in contact with, and then use the information. Charts are published showing the characteristic sparks of several types of steels, but the most satisfactory way is to make two test blocks of each type or brand steel used, having one block hard and the other in the soft or annealed condition, and keep them handy to the emery wheel. It is necessary to have both the hard and the soft blocks, as a material difference may be noted between the two states. This difference is especially noticeable in some of the alloy tool steels.

In studying the work as received for heat treatment consideration should be given to the question of whether or not it has been made from a sound piece of steel, and if it will respond to the quench. This question is controlled to a certain extent through a preliminary operation, that is, by having a test piece cut from each bar as received and making routine tests on it. It is hardened and fractured, chemical analysis made of it, and if necessary photomicrographic study made of it. In this way large segregations, seams, and cracks are located, and the grain size is checked for a quench from a definite temperature. Only after these tests have been satisfied are the bars released to the stock room.

The matter of design may be controlled within the plant, as the tool designer or engineer has in his control the location of holes and fillets, and the sizes of sections. If he appreciates the hardener's position he will do all in his power to see that as far as possible each part as designed will not present any unusual difficulties. Close co-operation between the designing and tool hardening departments will go a long way towards insuring the success of the latter.

The question of annealing before hardening is debatable. It takes a lot of time and in most cases is unnecessary. If considerable stock has been hogged off, or the piece subjected to any severe working a heating to just below the critical range is carried out to reduce the dangers of cracking and warping.

Another point to be considered is the plugging of the holes. Some holes must be left open to insure proper hardening. A steel plug, either screw or rod that fits snugly is used, as both fire clay and asbestos have a tendency to blow out in the quench. All holes near the corners of a rectangular section are always plugged. The writer believes that there is a critical section around a hole, or in other words, if the proper amount of stock in relation to the diameter of the hole is left between the surface and the hole, breakage will not take place. A circular section presents much less trouble than a rectangular section.

The foregoing points all deal with manipulation before the works enters the furnace. A great deal of the breakage that occurs in tool hardening is due to uneven heating, both as to the rate of heating, and as to the final temperature reached. The necessity of even and thorough heating is em-

phasized in all text books and papers dealing with the subject of the heat treatment of steel. If the furnace is maintained at a temperature above the critical range of the piece to be quenched, the chance for uneven heating is greatly enhanced. Sharp corners, projections, and thin sections at holes are bound to reach, and often pass through the critical range, while the body or large sections are below or in the critical range. Think of what takes place; think of the strains set up. Those parts below the critical range are expanding, those in the range are contracting, and those above are expanding at still another rate. It is these strains which cause the trouble of breakage and warpage. The characteristic break due to uneven heating is a shelling off of a corner or section, generally near a hole. The electric furnace is well adapted to obtain uniform heating as the rate of heating is under minute control at all times. However ,the electric furnace is not a cure all. The same thought, judgment, and care must be exercised as in using any other source of heat.

In production heat treatment of a uniform section, a rate of heating may be found which can be used day in and day out with uniform results, but in tool hardening where the size and section is always a variable, the rate of heating is a matter of judgment of the operator. A thorough preheating to around 900 degrees Fahr., where time and furnace capacity permits aids greatly in insuring uniform heating, and also shortens the time that the piece is exposed to temperatures above a scaling heat. For parts that are not to be ground, and which must be kept clean, such as gages, mold parts, etc., this preheating has been found to be absolutely necessary. The pieces are placed in a furnace the temperature of which is below the cirtical range of the steel from which they are made. The work and the furnace are allowed to come to the same temperature, and then the heat is applied at a rate to bring the steel slowly through the critical range and as far over as is necessary. The number of degrees over the critical range to which any particular piece is heated, depends upon the type of steel of which that piece is made, and upon the work it is to do. Holding of the work at the quenching heat from 2 to 15 minutes, depending on the size of the piece, does not harm the steel as far as the writer's experience has shown.

The quench comes next. Oil quenching steels offer small danger from cracks, but are subject to warpage. These oil hardening steels are all alloy steels and must be thoroughly heated to insure perfect solid solution of constituents if maximum hardness is to be obtained in the quench. The question of water or brine quenching is also debatable. The writer has found that brine does not cause breakage, and does at times give a little added hardness. In water or brine quenching the work is never allowed to become stone cold. It is always removed to an oil bath or into the tempering furnace while the surface is still above the boiling point of water. Experience must guide this operation to a certain extent, for if removed too soon, the heat retained in the center of the piece will progress towards the surface and cause the temper to be drawn above that desired, resulting in a soft piece. The tempering operation should be carried out immediately after the quench. All work is transfered to the tempering bath at once, with the idea of getting the strains relieved as soon as possible. The tempering is not rushed from this point on. Plenty of time is allowed for the work to reach the desired heat and this temperature is maintained for a length of time depending upon the size of the piece. A piece ½-inch in section has been held at the tempering heat for as long as 1½ hours without causing softening. After the tem-

pering operation the work may be cooled in any way desired, but a safety factor is provided by placing all pieces in oil to cool.

All pieces are now checked on the scleroscope to make sure that the desired hardness has been obtained. All data pertaining to the heat treatment is now entered on the report sheet, after which the work is delivered to the tool room. The writer's experiences are based almost entirely upon electric furnace heating, with both vertical and horizontal muffle types. All high speed steel parts are treated in an electric furnace. Two preheats are given to each piece, before being placed in the high temperature furnace. These preheats are carried out at approximately 1100 degrees Fahr. and 1550 degrees Fahr. The same exact records are kept of these tools. An optical pyrometer is extremely valuable in the treatment of high speed steel tools. The furnace may be run at a slightly higher heat than the parts are to reach, and by sighting on the work it can be removed from the furnace at just the right time.

An unique use of the optical pyrometer was recently observed by the writer, in the heating of a die block. It was necessary to heat the die block in a large, semi-muffle type furnace, where the couple was at a distance from the piece. An optical pyrometer was sighted on the piece to check the readings of the couple in the furnace. As repeated readings were taken a point was reached where the furnace temperature continued to rise while the readings of the optical pyrometer remained stationary. In effect, the optical pyrometer became a transformation indicator. When this particular piece was quenched no doubts were felt but that the critical range had been passed and the desired hardness insured.

To sum up briefly, the manipulation of tool steel under scientific methods deals with the following factors:

1. A close check on the received stock.
2. A study of each piece, and the work it is to do.
3. Heating to a temperature below the critical range to relieve badly strained pieces.
4. The plugging of all holes near edges or corners, especially in rectangular sections, with steel plugs.
5. The use of great care that the whole piece passes into and through the critical range as uniformly as possible.
6. In never allowing the piece to become cold in the quench.
7. The starting of the tempering operation immediately.
8. The keeping of accurate records of all operations to aid in checking up the piece in use.

THE CORROSION OF IRON AND STEEL

By T. S. Fuller

THE corrosion of iron and steel is a very old and broad subject and one which has puzzled mankind throughout the centuries. It is on account of this active tendency of things made of iron and steel to corrode and eventually to disintegrate that the early history of the metal is so much in doubt, and that it is so difficult to determine to what extent it was used by the ancients. The pyramids of Egypt which have been standing for five thousand years were built of granite blocks probably hewn out with iron tools and records show that during blasting operations in one of the pyramids in the year 1837, a wrought iron tool was discovered. Iron is mentioned in the Holy Scriptures in connection with the date 1200 B. C., and was known to the Chinese as far back as 2357 B. C. Probably the best known classical example of ancient iron is the pillar standing at Delhi, India, said to have been erected in 912 B. C. Nevertheless, in the face of this evidence, the early history of the metal is very much in doubt because of its disappearance through corrosion and subsequent disintegration.

For many years the people in this country as well as those of other countries have heard much of the so-called conservation of natural resources movement, and of the substitution of materials which are found in large quantities for those which are less plentiful. In this movement of universal conservation of natural resources, probably no two materials are any more important than iron and coal. When it is considered that four tons of coal are required for the smelting of every ton of finished iron, and that the coal supply in the United States is estimated to be sufficient for our needs for the next six thousand years at the present rate of consumption, or for but one hundred and fifty years if the present rate of increase continues, the importance of the problem becomes immediately apparent.

To those who may not be entirely familiar with the various problems of corrosion, it may be well to state that the yellowish brown substance which forms when moisture is allowed to act on the surface of articles made of iron or steel is rust. To the person who has carefully observed and studied the mechanism of corrosion, the nature and the distribution of the rust becomes of greatest importance to him. Therefore, in order that we may all have a general viewpoint we will briefly review some of the theories which have been advanced in efforts to explain the various corrosion phenomena.

Corrosion was first considered to be a case of simple oxidation similar to that taking place when iron is heated in air. It was soon discovered, however, that not only was the presence of oxygen necessary, but also the presence of liquid water. This discovery led to the acid theory of corrosion which takes into account the necessary liquid water and oxygen, and postulates, in addition to these the presence of an acid, usually carbonic acid. The acid is assumed to unite chemically with the iron, forming a soluble ferrous salt, which is later oxidized to ferric hydrate or rust, liberating the acid radical for further attack upon the iron. By this method it is quite evident that very minute quantities of acid will be sufficient to cause corrosion.

In 1903, Whitney[1] announced the results of experiments which lead to the electrolytic theory of corrosion. Distilled water was boiled in test tubes

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1. Journal of American Chemical Society, 1903, 25, 394.

to expel all the air and CO_2; polished samples of iron were added and the tubes sealed while the water was boiling. These tubes were left in this manner for weeks without the slightest appearance of rust on the surface of the iron or appearance of a corrosion product on the glass or in the solution. At the end of several weeks the tubes were opened and a small amount of air admitted. A precipitate of ferric hydrate quickly settled out. Dr. Whitney's interpretation of the results of this experiment is that iron goes into solution in pure liquid water until the water becomes saturated with iron ions and a state of equilibrium is established. Until oxygen is admitted no precipitation of iron takes place. The conclusion is reached that iron goes into solution in liquid water in the absence of both an acid radical and oxygen and that corrosion is, therefore, essentially an electrolytic phenomenon.

The hydrogen peroxide theory postulates the presence of this substance as an intermediate product in the formation of rust while the biological theory regards the corrosion of iron as a phenomenon, due primarily to microorganisms.

A more recent assumption in the list of corrosion theories is that announced by J. Newton Friend, presented at a recent meeting of the American Electrochemical Society, and called by him an auto-colloid catalytic theory of corrosion. Friend regards the corrosion of iron as a colloidial phenomenon, corrosion taking place by alternate reduction and oxidation of ferric hydoxide hydrosol. This theory is of too recent origin to have attracted a great deal of discussion up to this time, and of the others only two, the acid and electrolytic theories have been seriously considered by students of corrosion. It is a very difficult matter to say which of these two views is correct, because of the difficulty of getting extremely pure substances to work with, but the writer believes that it is safe to say that ninety per cent of the students of the corrosion of iron prefer to regard it as an electrochemical phenomenon.

Considerable impetus was given to the study of corrosion by the experiments of Whitney, which lead to the electrolytic theory. Later, Cushman and Walker developed a reagent which became known as ferroxyl indicator, which demonstrates quite clearly the nature of ferrous corrosion. The indicator has been described in detail in a book by Cushman and Gardner, entitled "Corrosion and Preservation of Iron and Steel." Briefly, it may be prepared by mixing dilute water solutions of phenolphthalein and potassium ferricyanide. If a more or less permanent record is desired, the solution is thickened with gelation or agar-agar. The action of the ferroxyl indicator is this—a solution containing phenolphthalein becomes pink in the presence of an excess of hydroxyl ions; potassium ferricyanide in the presence of ferrous ions forms the characteristic Turnbull's blue compound; therefore, with the indicator in contact with an iron surface, the positive areas, for example, points where iron is going into solution in the ferrous condition, are colored blue, and the negative areas, where there is a predominance of hydroxyl ions, are colored pink by these ions. The writer suggests that those who are inclined to doubt the electrolytic nature of corrosion phenomena, try a few experiments with the ferroxyl indicator. The results are startling.

The rate of corrosion of every piece of iron or steel depends upon the individual conditions existing in the particular locality in which the metal is in use, as well as upon the means which have been taken to prevent corrosion. Bearing in mind that the two substances besides iron which are

necessary for ferrous corrosion, are liquid water and oxygen, corrosion phenomena are of many types. Iron samples, wholly immersed, corrode faster if the water is moving rapidly than they do if it is in a state of rest. The rate of corrosion of iron tanks or pipes holding water is much less if they be kept full than if they be alternately empty and full. Atmospheric corrosion proceeds much more rapidly in districts where the atmosphere is chemically polluted by sulphur vapors and the like, than it does in districts where the atmosphere is free from contamination. The corrosion of iron or steel is accelerated by contact with an element, such as copper or tin, electropositive with respect to iron, while on the other hand, corrosion is retarded by contact with an element more electronegative than iron, such as zinc. The corrosion rate increases with rising temperature. The rate of corrosion is also dependent upon the character of the steel as determined by its chemical composition and heat treatment. Steel containing small amounts of copper or nickel resists atmospheric corrosion better than pure iron. The well known stainless steels containing large amounts of chromium are highly resistant to corrosion.

The writer has found that much may be learned in a very short time about the corrosion resisting properties of a steel by observing the action of a drop of water upon the polished surface of the metal. These experiments have been described in detail before the meeting of the American Electrochemical Society in April, 1921, and will be briefly reviewed here.

Drops of distilled water in equilibrium with the air of the laboratory were placed upon various steel surfaces. In the case of pure iron corrosion began almost immediately, and at the end of a few minutes the corrosion product could be seen distributing itself, always according to the same pattern. Three distinct zones developed; an outer one, which has been termed the immune zone, an inner one, which occupied a large part of the area of the drop, and a wall zone, which lay between the outer and the inner zones. The outer zone was perhaps a half millimeter in width and the wall zone was best described as a line. The iron rust was evenly distributed over the inner zone, and was piled up to a high level on the wall zone, and the outer or immune zone was entirely free from deposits of any kind. Ferroxyl indicator showed pink over the outer zone, indicating a negative area and that at this point no iron was going into solution, and blue over the inner zone, showing that corrosion was taking place over the entire central portion of the drop. The length of time elapsing before the first appearance of rust, and the amount of rust present after the drop had evaporated, varied greatly with different steels and form the criterion for judging the corrosion resistance of the particular steel under examination.

Much has already been accomplished in the manufacture of rust resisting steels, or at least steels which rust less than pure iron, and much remains to be done. Examples are the steels containing chromium and the copper bearing steels which have been mentioned elsewhere in this paper. Of course, the ideal steel would be one having a low cost and showing no corrosion—a goal to be striven for, but probably never to be attained.

Protective coatings for iron and steel form an important section of metal technology. Various, specially prepared paints are in use, together with coatings of zinc, tin, or copper applied in different ways.

Of late much has been said and written about the deactivation of water. In general, the scheme consists in passing the water to be used in a given closed system over scrap iron, to remove the dissolved oxygen. Once the

oxygen has been removed, theoretically the water may go on circulating indefinitely in the system without corrosive action. Such installations have proved to be very successful. Iron may be made immune to corrosion by making it cathode, that is, by making it the negative pole in a cell, with a potential just sufficient to balance the solution pressure of the metal. This method is not used extensively because it is costly.

The general problem of corrosion is one which should be of the very greatest interest to all users of iron and steel; and that includes all of civilized mankind, and it is most desirable that all should have as comprehensive an understanding of the subject as possible. There are many things which are as yet unexplained, but certain facts are so well established that they may be wisely borne in mind. Therefore, in summarizing the foregoing we find the pertinent points, as follows:

1. Two substances, liquid water and oxygen are necessary for the corrosion of iron.

2. The rusting of iron may be best regarded as an electrochemical phenomenon.

3. The rate of corrosion of every piece of iron or steel depends upon its composition, upon the means taken for its protection, and upon the individual conditions existing in the particular locality in which it is in use.

4. Much may be learned in a very short time about the corrosion resisting properties of any sample of iron or steel by observing its behavior under the action of a drop of water.

It is to be hoped that the effects of those now at work on the various problems of corrosion, and the efforts of the investigators to come will help to clear up the anomalies which still stand in the way of a complete understanding of the subject.

Some notes on the Inspection of Steel for Automobile Use

(*Continued from page* 46)

time the hammer is elevated the test piece is rotated one half turn so that successive blows are delivered on opposite sides. Failure, in the form of a fatigue, progresses from the opposite sides until finally the section becomes so reduced it snaps off in tension. An automatic switch stops the machine when failure occurs and a recorder totals the number of blows. The number of blows obtained on the piece under test is compared with those previously obtained on other pieces of the same type of material which have stood up well in service and the material is judged accordingly.

Conclusion

Experience has shown that by purchasing steel from a reliable source where reasonable precautions are taken to produce sound stock, by making suitable physical tests on representative specimens, by brinelling each piece, and finally reading the individual test fracture, one can hold failures to a negligible quantity.

A NEW TYPE AUTOMATIC TEMPERATURE REGULATOR AND ITS APPLICATION TO HEAT TREATING FURNACES

By R. W. Newcomb

ALMOST every problem of automatic temperature control differs in one way or another from every other problem. The fuel that is used may be gas, oil, coal, or electricity. A great variety of burners are found, furnace construction differs, the results to be obtained may be entirely different and so on. Each installation must be considered as a separate problem. It is not difficult to design an automatic regulator which will fit one or two conditions but to make one sufficiently flexible in its adaptability and in its adjustment to fill all these requirements is another matter. This was our problem or part of it. There were certain other requirements to be met, the control over the ratio between gas and air on gas fired systems or over oil and atomizing agent on oil systems. On electric furnaces it is sometimes necessary to control the adjustment of a rheostat or to operate a circuit breaker, and sometimes to operate several series switches on the primary connections of a transformer. Many plants have all of these different conditions to meet. It was desired therefore to design a regulator which would cover the widest field and which would permit a customer to standardize on one type of machine even though he had a wide range of conditions to meet.

From the above it was not hard to lay down the fundamental specifications.

1. Dependability under which should be included accuracy, constancy, simplicity and power.
2. Flexibility in its adaptability to gas, oil, powdered coal or electricity.
3. Adjustability in that it must be possible to adjust the range, speed and magnitude of control to cover a wide temperature range and also diversified furnace and burner construction.

The element of cost did not enter into the matter in the least. In automatic temperature control it is day in and day out dependability that is wanted, the factor of cost should be and usually is the last consideration.

Two views of the machine is shown in Fig. 1 and Fig. 2. It is the result of about three years of careful development. The regulator itself is made up of four parts; the frame and bed plate; a 1/12-horsepower motor with worm and worm gear speed reductions; an escapement or ratchet mechanism and a contactor. On the ratchet wheel spindle a sprocket is mounted. This sprocket is connected by a sprocket chain to another sprocket wheel attached to the valve or other appliance which is to be regulated. In case gas and air or several valves are to be regulated at once then this connecting sprocket chain runs over each of the sprockets mounted thereon. When either one of the solenoids is energized, then one of the pawls of the escapement mechanism engages with the ratchet wheel and moves it in one direction or the other depending upon which pawl is engaged. The movement of the ratchet wheel depends upon the setting of the wrist pin in the cam. It can be set to pass only one ratchet tooth each vibration of the escapement lever or up to a maximum of four teeth. The total angular movement of the ratchet may be limited to 220 by filing away four consecutive ratchet teeth. By selection of the proper sprockets this can be made to correspond to fully open and fully closed valve positions.

A paper presented before the Indianapolis Convention. The author is connected with Charles Engelhard, Inc., New York.

The escapement lever vibrates in one direction about once in five seconds. If the wrist pin in the cam is set so that only one ratchet tooth is passed each vibration, and if the solenoid controlling the pawl is energized for five seconds, then the ratchet spindle movement will be 1/50th of one revolution for there are fifty teeth on the ratchet. If the sprocket ratio from regulator to valve is 1 to 8, then the valve is moved 1/400 of one revolution. This is a much finer adjustment than is possible by manual control. If the solenoid is energized for 10 seconds, double the adjustment is made for then two vibrations of the escapement lever are effective. As soon as the solenoid circuit is broken, the pawl takes up a neutral position and no further adjustment takes place until one or the other of the two solenoids is again energized.

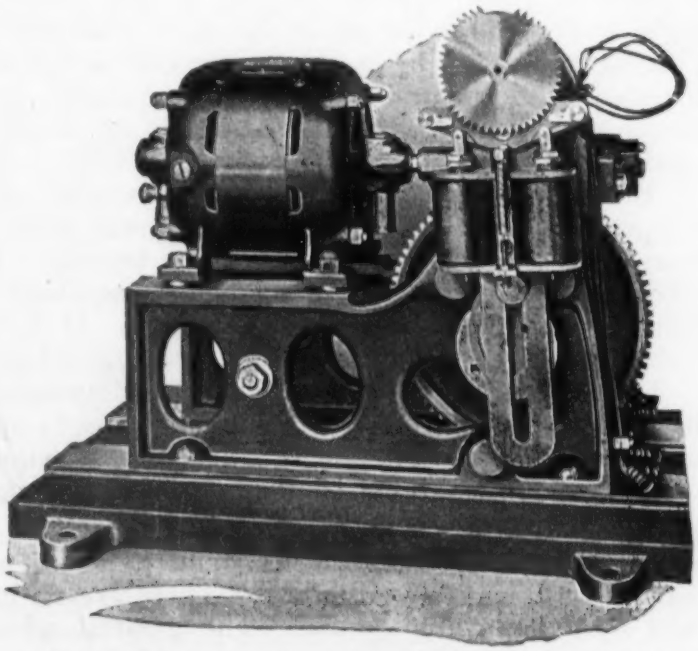

Fig. 1—Shows one view of regulator control mechanism.

From this can be seen that the speed of control is not only a function of the setting of the wrist pin and of the time during which one or the other of the solenoids is energized, but also the frequency with which one of these solenoids is energized. In other words, if a solenoid is connected in circuit only for five seconds once in 12 minutes and otherwise as given above then the valve adjustment can only be 1/400 of one revolution in twelve minutes. If the solenoid is energized once every half minute then the speed of adjustment will be 24 times as fast. Carrying the possibility of speed control to the other extreme, if we have a sprocket ratio from regulator to valve of 8-1 instead of 1-8, if the cam wrist pin is set to increase the amplitude of movement on the pawls so that four ratchet teeth are passed each vibration, if the solenoids are energized for twenty seconds and if they are connected in circuit once in 40 seconds then the speed of valve control will be 3.41 revolutions of the valve every 40 seconds. This entire range of adjustability from 1/400 of a revolution in 12 minutes to 3.41 in 40 seconds is equivalent to 24532 per cent.

The solenoids are controlled electrically from the maximum and minimum contacts in the temperature measuring instrument. When a thermostat

serves for this purpose then the neutral lead connecting it to the solenoids is connected in series with a contactor. This establishes the circuit at certain intervals and for a certain length of time only. Both the interval and the period are adjustable. The former between limits of 40 seconds and 12 minutes, the latter from 0 seconds to 40 seconds. The contactor is mounted on the opposite side of the regulator away from the cam.

When an electric thermometer or thermo-electric pyrometer serves as a measuring instrument, then the contactor works in a little different way. The maximum and minimum contacts are in the form of arced plates electrically insulated, separated by a very narrow gap and counted on the scale of the instrument in such a way that they can be adjusted to almost any point on the temperature scale. The pointer swings above them. It is provided with a platinum point vertical to the contact plates. Above the pointer and bent to correspond to the arc of the scale, a chopper bar is pivoted. This chopper bar is controlled by a small solenoid within the instrument case. It is connected to the neutral circuit of the solenoids on the regulator while the maximum plate contact is connected to the other side of one regulator solenoid and the minimum plate to the opposite side of the other regulator solenoid. From this can be seen that to energize either regulator solenoid the chopper bar drops and presses the platinum point in the instrument pointer down against one of the contact plates beneath. This completes the circuit to one of the solenoids. If the pointer was above the minimum contact plate then the valve is made to open slightly. If it was above the maximum plate then the other regulator solenoid is energized and the valve is closed slightly. The interval at which the chopper bar operates and the time during which it is down is the main controlling factor as to speed of adustment before mentioned. Therefore, if we connect the solenoid which controls the chopper bar to the contactor on the regulator, we can adjust these functions over a wide range.

Another important point aside from this great range of adjustability is that the whole apparatus is entirely automatic. There are no clocks or other parts which could introduce complications. The greatest advantage in this type of regulator compared to those that operate on a bypass and are either all open or all closed, is that it operates to correct wrong tendencies rather than extremes of high or low temperature.

You may be asked what is the advantage of a control which so operates, that it slightly increases or decreases the heat as compared with one operating on the fully opened and fully closed principle if the latter apparently do control furnace temperatures within the same temperature limits. The answer is this. Is it not logical to suppose that with enough fuel controlled through a bypass on the "all off" and "all on" system that there is enough under control to take care of pressure variation, clogging burners, opened and closed doors, etc., that with such an amount of fuel, that when the valve is opened the temperature rapidly increases, whereas, when the valve is closed there is a comparatively fast dropping off of temperature. The lag of the furnace and of the thermocouple enters in to such an extent that while the thermocouple may show a control within narrow limits, actually there is a much greater fluctuation in the area nearer the source of heat. When the regulator is capable of making a very slight adjustment and then only when required, and at the same time has a range to more than cover the extremes of temperature required, then the curve of furnac temperature instead of being a saw toothed affair, which does not in all proba-

bility indicate the actual extremes of heat, becomes more of a waved line, indicating a uniform furnace temperature throughout.

On oil fired systems the bug-a-bear of automatic regulation is clogged burners and change in the viscosity of the oil. With the regulation described they are handled the same as they would be by manual control. When the temperature drops for any reason clogged burners, lower viscosity or a drop in pressure the machine simply proceeds to open up the oil, and the air or steam valve and in exact accordance with a predetermined ratio.

On electric furnaces controlled by taps of a transformer it is possible to replace the usual knife switches or breakers with a controller which is of rotary form with carbon contacts. With the adjustability and flexibility provided, the same machine can be made to fit almost any condition of control, without changing its construction. It is only a question of properly

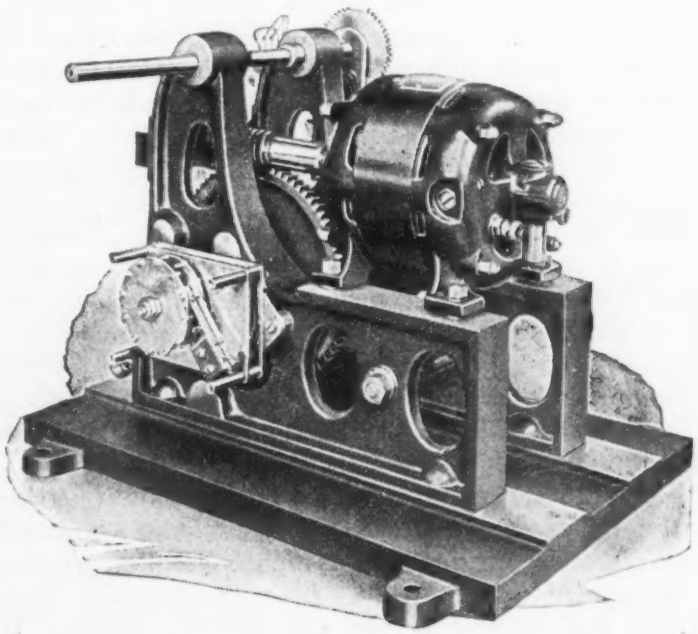

Fig. 2—Shows the opposite side view of regulator control

relating the size of the sprocket on the machine to the sprockets on the rotatable member which is to be controlled.

It needs hardly to be explained that the sentivity of the measuring instrument, the lag of the thermocouple and the location of it in relation to the source of heat, are factors of much importance. However, it is sufficient to say that the lower the range the closer the control as a rule, in terms of degrees. A very sensitive control is obtained through the medium of a thermostat for a range up to 300 or 350 degrees Fahr. For the range 350 degrees Fahr. to 1300 degrees Fahr. a differential instrument can be used in connection with the resistance thermometer. This makes possible a full scale range on the instrument of plus and minus 50 degrees Fahr. or less. When so calibrated very close regulation is possible.

An equipment is now under construction upon which a guarantee of control within plus or minus ½ of a degree Cent. has been given. Under ordinary conditions in a well designed furnace it is possible to control with

an accuracy of plus or minus 10 degrees Fahr. This limit is given on average furnace temperatures and not on control as indicated by the thermocouple used by the control equipment itself.

Particular notice is directed to this, inasmuch as a curve plotted from temperatures shown by this couple will almost always show a close control, if the instrument and regulator are sensitive. It is average furnace temperature that counts and it is the writer's contention that a better and more uniform temperature control is obtained when the regulator makes only the very slight adjustments necessary to carry an even heat.

To obtain the same effect from a system operating on the "all on" and "all off" principle then such a very small amount of fuel is under control as compared to the total amount used that a great deal of time is lost in bringing the furnace up to heat after a new charge is put in. In any case the amount of fuel under control must be enough to take care of any change in pressure to which the moving system may be subjected.

Before closing this paper the writer wishes to mention the system of automatic regulation of temperature along a predetermined time-temperature curve. This is much more difficult and complex than when regulation at a fixed temperature is wanted. Several instruments have been designed and patented for this purpose. The main difference between them and those for control at a fixed point is that the maximum and minimum contacts have to be moved across the scale in accordance with a certain time curve previously determined. Some do this by using a cam driven by a small motor or other power. This cam is connected in such a way that the contacts are advanced a certain number of degrees at a certain time rate. This rate need not be represented by a straight line curve. The instrument used with the regulator above described has its maximum and minimum contacts in the form of thin plates mounted around a drum. They are electrically insulated from each other and are separated by a narrow gap or line. If these contacts were laid out flat, this gap would be the curve of the temperature control desired. The drum is driven at a certain speed, therefore, the gap between the contact plates on the drum just beneath the pointer is constantly changing its position. In other words, the point at which control is obtained is constantly changing and in accordance with the time temperature curve laid out, is represented by the gap separating the two contact plates. It is as easy to change drums as it is to change a phonograph record.

When the regulator described in this paper is used to control the temperature of a furnace according to a time-temperature curve it is as capable of close control at the lower range as at the higher range, because the units or magnitude of each adjustment is the same in either case.

STEEL TREATERS—"WE ARE GUILTY"

By Edmund Blasko

SEVERAL criminals were on trial in New York the other day and the conscience of one of them was worrying him so much that he confessed. He became the chief witness for the State and as a reward, the charges against him were dropped and guilty though he was, he escaped punishment.

So is my conscience troubling me. We are not on trial yet, but you can hear charges against us. It is mostly inefficiency of heat treating equipment and slow progress. Heaven knows but they sound rather familiar. I feel somewhat uneasy. I believe I'll confess and offer the evidence voluntarily.

Steel Treaters, we might just as well all confess, "We are guilty."

We are guilty of inefficiency.

We are guilty of slow thinking.

We are guilty of having faulty heat treat layouts, of using unfit transportation methods.

We are guilty of negligence.

Have you ever had a device made, of which you just had a faint idea how it will work?

Did you ever try some instrument in a furnace which did not work very well when the furnace was cold, nevertheless, you thought it may work when the furnace is heated up?

Did you ever quench steel heated well above or below the temperature it should have been heated, thinking it would be good enough?

Did you often try to put something over the metallurgical department by changing the standard heat treatment of steel; and you thought it was all right, because you got away with it?

Do you feel guilty?

We are guilty of using obsolete furnaces, of indifference to progress, of not giving a fair chance to new developments. Sometimes you see a worthy implement at the Convention exhibition that has never been given a thorough test and so does not find its way into general use.

We are guilty of a naughty sin; of being satisfied with ourselves, not to say proud of ourselves.

Why, some of us pride ourselves of being able to make a piece of steel hard and a hard one soft, though in neither case may the steel be in the right condition; and many of us feel proud of being able to build a heat treating furnace, though it may not be possible to heat it anywhere near uniformly.

We hear of others progress, but just as if we were nailed down, we stand still—we don't follow them.

As you see our sins are numerous, though these may not be all.

If you feel guilty of some of these or of some other sins committed against common sense heat treating, bow your head, put ashes on it and re-

A paper presented before the Indianapolis Convention. The author, Edmund Blasko, is connected with the Ford Motor Company, Dearborn, Mich.

pent, for you sinned against your common sense. May the God of steel treaters forgive you.

We feel better after our confession. We ought to. To realize our faults is half removing them. It should not be very hard to get rid of the rest. Yes, we have made many mistakes—we did not excell in our first attempt, but we will have a new chance. We will build a new heat treat, profiting by our previous errors and we will equip it so as to avoid the many mistakes we made before. We will have an opportunity which few of us have: To do it over again.

Suppose we have an opportunity to build a heat treating department as part of a manufacturing plant with a fairly large production, automobiles for instance. We will only consider the production heat treat and not a complete layout even of that, just rough it out. Let us try to use our much valued but less used gift: Our common sense.—

First of all we have to make a preliminary layout of the heat treat and also of the shops where heat treated parts are machined, as they are so closely related to each other that we should never make a layout of one without considering the layout of the other at the same time. To make a general layout, one should possess power of imagination, one should be able to visualize the continuous flow of material in all the shops, then put his vision on paper.

As labor is the most expensive item in heat treating, the first consideration should be the elimination of manual labor as much as possible in every production heat treating department. First of all, eliminate labor in the transportation of the parts from the machine shop to the heat treat and vice-versa. The general practice is to put up a separate heat treat building somewhere near the machine shop and truck the heat treated parts to and from the heat treat. But is this right? No, by no means. The machine shop will certainly be laid out so that all parts, while being machined will advance in one general direction, that is toward the assembly, with the aid of a conveyor system. Why should the heat treating department be an exception to this rule? It should not be. Some of the parts will be heat treated before machining and some both before and after machining. Some of those that are heat treated after machining will have to come in the machine shop for grinding.

It is evident that if we put the heat treating department in a separate building, it will require several transportations between the two departments. This is very inefficient. The solution is that the heat treat should be in the path of the machining operations to harmonize with the rule that the machined parts—in order to avoid unnecessary transportation—should advance continuously towards one point, the assembly or shipping,. whatever the case may be.

This will, of course, divide the heat treating department in two parts; a heating department for parts before machining and one for parts after machining. The first will include the annealing of all parts before machining; also the hardening of those forgings that are drawn at a high enough temperature to permit their machining. The second which we may call the hardening room will be for the hardening of all machined parts. The two heat treats are separated by that part of the machine shop, where the heat treated parts are machined. Next to the hardening room should be located the grinding room where the grinding after hardening is done.

The layout should be such that on stock conveyor (with several drives if necessary) would carry the parts from the annealing room to the ma-

chine shop, from there into the hardening room and then into the grinding department. This arrangement may be unusual, but it is the correct one. Why should the annealing for rough forgings be carried out in the same room with the hardening of finished parts? We never think of sorting the lathes, millers or drill presses in a production shop, so why should we keep the annealing and hardening rooms together? The separation cuts the transportation cost to a fraction of what it would be by sending the parts back and forth between the machine shop and heat treating department. There is no reason why we should harden the parts in the same room in which we anneal them, in fact, there are some who believe that the furnaces should be scattered in the machine shop, each furnace built for certain part and placed in its respective department.

This would hardly be the right solution though. It requires too many small units and the more and smaller units we have, the more inefficiently we work. Also the floor space required with such layout would be many times that of a concentrated heat treat. The machine shop would be encircled with a number of different pipings and if any of the furnaces would be out of order, it would be rather difficult to heat treat those parts in other departments. There might be a reserve furnace in every department, but its cost would prohibit this, while in a concentrated heat treat, it is not difficult at all to provide a reserve furnace unit. Therefore, those parts of the heat treat that do the same kind of work should be concentrated but located properly in relation to the machine shop to insure cheap transportation.

Next we have to plan the annealing room. For annealing in large production, we should not consider anything but continuous furnaces. They relieve the furnace operator of quite a lot of work and thus make it possible for him to handle much larger tonnage per day. Continuous furnaces satisfy the proper heating better than the old square furnace with doors at the front. The heat is more uniform. There is a gradual increase in temperature from the feeding end to the unloading end. The furnaces can be built in much larger sizes without being awkward to handle. Every part of the furnace is approximately at constant temperature, which saves the furnace and insures for every piece the same rate of heating. It makes the work less difficult for the men, which in turn means a savings in labor. Also it is much easier to hold the heat constant, as it requires but little adjustment on account of the constant uniform feeding. It saves floor space. In fact anywhere where production allows its use, its advantages are so obvious that it prohibits the use of the old square furnaces with doors at the front only.

Continuous furnaces require some mechanical device to move the pieces through the furnace or if it is an inclined furnace for round stock, a stop device that holds them and lets out a certain number each time. Some steel treaters seem too prejudiced against all kinds of mechanical devices on heat treating furnaces; undoubtedly the chief reason for this is their unfortunate experience with a few inefficient devices. Some of them made up their minds that no device will work with a furnace, but the right ones will. There are many of these continuous furnaces in operation and most of them are very successful. The capacity per square foot of space it occupies is several times larger than one of the larger furnaces. Of course, we should not adopt them unless production warrants their use. We should build as large annealing furnaces as production permits. The annealing room will also include the hardening and drawing furnaces for those forgings that after being hardened are drawn at a high temperature to permit their ma-

chining. The forgings should be lifted from the quenching tank by means of a conveyor and deposited at the feed end of the drawing furnace or taken through the drawing furnace with the same conveyor. After the forgings leave the annealing or drawing furnaces, they may be allowed to cool on the floor, but most of them can be cooled in luke warm water right away. Dropping them in water from a temperature below 1000 degrees Fahr. does not effect their hardness, but it makes their cooling uniform, besides facilitating their handling a great deal, as the forgings can be handled with gloves and thrown on the machine shop conveyor without the necessity of piling them up inside or outside of the heat treat at the cost of additional transportation.

An annealing furnace 42 inches wide inside and 20 feet long with a 7-foot long heating chamber would have a capacity of approximately 1500 pounds of forgings per hour, or 18 tons in 24 hours and the same size hardening furnace about 1000 pounds per hour or 12 tons in 24 hours, as the pieces could not be piled up in it. So to take care of about 36 tons of annealing and 24 tons of hardening and drawing, it would be sufficient to install three annealing furnaces—the third one as a reserve, and three sets of hardening and drawing furnaces, including one reserve set to be used while some of the other furnaces are in repair or to catch up with the production occasionally. As for the fuel used in the furnaces, that depends on plant conditions entirely. Electric furnaces may be prohibitively expensive in the annealing room, but they certainly should receive first consideration in the hardening room. The hardening department receives the parts from the machine shop on the same conveyor. This is where we need a great deal of improvement, as here it is where our inadequate and improper methods stand out boldly as a monument to our inefficiency. The bulk of the work in the hardening room of an automobile plant consists of gears and this is what I have mostly in mind.

You can see all over in heat treat departments how they harden gears and other finished parts in air furnaces. Of course they get scaled. To remove the scale they brush, sand blast or tap them with small hammers. Usually we get away with this scale unless there is a key way, splines or some threaded section on the pieces but once in a while with a little carelessness this scale cannot be removed and we spoil thousands of pieces this way. There are some electric furnaces that reduce scaling to a minimum, but they do not entirely eliminate it, the parts must be cleaned from the scale.

After the scale is removed, the parts are drawn in semi-muffle furnaces or in oil baths, depending on the drawing temperature.

New type furnaces should be developed for the hardening of finished parts, such as gears. We should be able to eliminate the many operations and numerous handlings. The future furnace should be a continuous furnace with automatic feed and discharge capable of a fairly large production and of such construction that will allow parts to be quenched in any position desired. Also as a step further, it should be built in combination with drawing furnace. This might be air drawing furnaces instead of oil baths. It really should be an electric furnace with an automatic temperature regulator, so that one man could handle three or four of these furnaces. The furnace

must be as scale proof as possible. This is the coming furnace for finished parts, but, of course, it should be sold at a reasonable price to insure wide use.

Many of us think that electric furnaces are an expensive luxury. There may be some cases where they are, but in many cases, the cost of heat treating could be made actually cheaper by using electric furnaces. Even if the power rate is high, the possibility of reducing labor expenses, would compensate for the additional cost of operation. Electric furnaces are very easily adapted to labor saving devices, and automatic equipment.

In conclusion the writer wishes to point out some of the defects in our heat treating methods which could be improved upon. To eliminate them we need more thinking, more fresh ideas. We have to think, think and think, then get together and exchange ideas. We should have frequent round table talks. We should experiment, do development work side by side with our every day work and let others know the results. It is only good common sense policy; the next one will continue where we left off, instead of starting it all over again. Spread your knowledge liberally, as it pays.

Do not fear to tell what you know, for secretiveness will prevent you from acquiring additional knowledge. Individuals alone can make but slow progress. We need the help, encouragement and criticisms of others. We have to know what others think of our ways. This does not necessarily mean that we have to follow their views, even if no one agrees with us—after all, our ideas may not be correct and righteous criticism will be helpful. If problems come up in regard to heat treatment, talk it over with others in the department. Listen to different opinions no matter how much better you may think your suggestions may be. It will serve a double purpose. First, they may have very good suggestions that will help you, second, this will encourage them, stimulate their desire for more knowledge and force them to think.

All that is written above could be put in a few words; ACQUIRE AND USE YOUR COMMON SENSE. You may have it by birth, but you can acquire it by study. A man blessed with common sense, ambition to learn and willing to work, can do anything.

You need common sense in your everyday work, you need it in your every day life. It is so simple; still there is something awe inspiring in it. We admire it in others, and the knowledge that we can acquire it brings it close to us. If we could ever re-create the ancient gods, we should create one for common sense. It is worth anything to acquire, as it is worthier than riches, more useful than genius, the greatest gift you can be blessed with: COMMON SENSE.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 46. Is the practice of buying high-speed steel by brand names instead of physical, chemical and metallurgical specifications justifiable?

QUESTION 47. What is meant by "secondary hardness" in the tempering of high-speed steel.

QUESTION 48. What are dendrites and how may they be detected?

QUESTION 49. Can dendrites be removed through a proper heat treatment?

QUESTION 50. What is the chemical composition of the so-called "stainless steel" used for cutlery purposes?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 30 How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?

ANSWER. By C. W. Bell. Lately there has been a good deal said about the energizers, kind of charcoal, kind of coke, etc., which are best for use in the manufacture of a carbonizer. The man who uses the material is not interested in how it is made but in the results which it gives him. Therefore, in testing the merits of different compounds, the one which gives the desired case and carbon content in the quickest time and which repeats these results day after day and at the least cost, is the best compound regardless of the kind of energizer it contains or the source of its charcoal.

Therefore, in choosing compounds, tests should be run to determine which compound produces the desired results in the quickest time, and

this can be ascertained by running the different compounds in the same sized boxes, containing the same number and size of steel pieces, packed in the same furnace and inspecting the results for depth of case and carbon content.

This test should be repeated for each compound time after time and inspections made of the pieces after each heat. The compound giving repeatedly the same depth of case and carbon content will prove its reliability.

It is customary in production to use a compound in the proportion of one part of new to three parts of old. Therefore, in making test runs this same proportion should be followed. By keeping account of the total weights of new compound used in the above tests and figuring these weights at the cost per ton, the most economical compound to use can be easily ascertained. The compound which is superior in these three points of efficiency, reliability and economy should be the compound selected, regardless of the energizer used.

Some compounds are very dusty when received, some of them generate an excessive amount of dust in use, some of them have both of these drawbacks. The compound which is clean and produces the least amount of dirt in use is very desirable and this point should be given very careful consideration.

To summarize; select the compound which gives the results you want in the quickest time repeatedly at the least cost and which is the least dusty. There are other points of minor importance but these are the most essential.

QUESTION NO. 35. What is the difference between red annealed and blue annealed sheet steel?

QUESTION NO. 38. What regulations are recommended to reduce the fire hazzard of quenching tanks?

QUESTION NO. 40. What is the influence of a low percentage copper content in steel?

ANSWER.—Numerous and varied statements have been given in reference to the beneficial effects of a low copper content in a steel. The chief benefit, apparently is that it retards atmospheric corrosion. It has been stated, however, that a copper bearing steel is not particularly resistive to salt water. The copper content is usually less than 0.30 per cent and this addition to an ordinary steel does not apparently interfere with the tenacity or ductility of the steel.

Severe corrosion tests made by various research organizations have shown a marked superiority in the resistance of the copper bearing steels over the non-copper bearing ones as well as wrought iron. Such a steel has been reported to outlast similar steels without copper from 3 to 5 times. An ordinary steel having a high sulphur content is usually less resistive to corrision than a lower sulphur steel, however the presence of copper up to 0.30 per cent appears to neutralize the bad effect of the sulphur. A copper content of 0.10 per cent will neutralize sulphur up to 0.05 per cent.

QUESTION 41. Is the X-ray examination of steels commercially practicable?

QUESTION 42. *Why should high speed steel be delivered only in the annealed condition?*

ANSWER. High-speed steel should be delivered only in the annealed condition because annealing relieves the internal strains inevitable in the manufacture and puts it in vastly improved physical condition. The manufacturer's inspection after annealing also discloses defects not visible in the unannealed state.

QUESTION 43. *What is the role of Chromium and Vanadium in steel?*

ANSWER. From a paper by F. J. Griffiths presented at the Twentieth annual meeting of the American Society for Testing Materials.

Chrome-vanadium steel holds the position virtually at the head of the commercial alloy steels, and owes this prestige to the extremely wide range of physical qualities which are capable of being developed from this metal by proper methods of heat treatment. Like all alloy steels, it is as its earlier name signifies, a special steel, meaning not only that it is designed for special purposes, but also that its preparation for the particular work it is called upon to perform must be carried out along certain lines calculated to yield in the final result, those qualities which shall represent 100 per cent efficiency in the final product. Many specifications today allow a variation of 1 or 2 per cent in the elongation, and restrict also the ultimate strength and yield point to extremely narrow limits. Examination of these specifications alone would serve to show the wide range of qualities of chrome-vanadium steel, and the absolute delicate accuracy with which by proper management it may be put into condition to perform its highest functions.

Chrome-vanadium combines in such a manner with iron that the separate constituents of the final alloy produced cannot be distinguished, regardless of the methods selected to separate them. Whether we adopt mechanical means or use the microscope under high magnification the result is the same; the discovery of a homogeneous blending of the allied elements which defies detection of the constituent substances. This phenomenon indicates a quite strong combination between the alloying elements and defines the combination unmistakably.

It is generally recognized that when one metal alloys with one or more other metals, its poperties are changed in a remarkable manner. The fusion may be lowered, the hardness and strength increased, the ductility affected proportionately and the transformation temperatures raised or lowered, depending upon the nature and characteristics of the alloying elements. Therefore, by properly alloying a metal, the properties of the resulting alloy may possess such profound qualities as to render it more adaptable for the purpose for which it was originally intended. It is the endeavor to decrease injurious properties and to increase the desirable ones. For this fundamental reason, the iron alloys have become to a considerable extent standardized. Those better known to metallurgy and fabricators are the nickel and nickel-chromium steels. Until recently, little investigation has been ventured to ascertain the definite properties of chrome-vanadium, and the advantages secured by this alloying element were relatively unknown ex-

cept to a favorite few, who, through their own research work, acquired intimate knowledge of the characteristics bestowed upon iron by the addition of this alloy.

Chrome-vanadium alloys with iron in all proportions and affects the properties to a marked degree, depending upon the percentage of chrome-vanadium present. The qualities which become inherent are influenced also more or less proportionately by the amount of carbon contained. In this respect chrome vanadium steel is a special steel in another sense of the word, and cannot be judged by the same standard as the old carbon steels.

The point of view of the examiner of the old commercial steel is always that of the actual condition in which the metal exists as he sees it before him, and governed by the amount of carbon present. But this point of view has altered gradually until with chrome-vanadium steel, the carbon range permissible to obtain specific characteristics has become narrowed. The presence of chrome-vanadium in steel intensifies the effect of the carbon in all the best qualities, which it is capable of producing alone. These increases take form not only in physical results, dynamic strength, resistance to wear, increased hardening power, lack of brittleness, etc., but also in purity, soundness and homogeneity of the metal. These are the specific contributions which chrome-vanadium brings to iron as compared to the older simple steel.

Unfortunately many of these qualities enumerated have no current and accepted method of measurement, whereby they may be offered on a basis for comparison. Figures may be, and often are, offered to show accurately the result of comparative tests which are intended as a means of comparison of the functions of a particular steel, but, ordinarily, the test conditions would vary so much under the manipulation of other experimenters that no comparable results are really obtainable. In any event, the data submitted usually mean nothing to the other man.

The property of soundness of the casting and ingots, produced by the use of chrome-vanadium, induces freedom from occluded gases and greatly increases the desirable physical qualities of the forgings subsequently made from this steel, such as strength, ductility and resilience. These desirable properties are amply proved not only from the results obtained from tests, but also from the more vital trial of actual use. The user of an alloy steel is concerned entirely with what ultimate qualities the metal is capable of developing, regardless of the experience with which he may have previously contended.

According to the old view and judging from the results of tests, chrome-vanadium steel, as rolled or annealed, may appear to be a worthless product. It may have a percentage of elongation, reduction of area, elastic limit and ultimate strength corresponding to simple carbon steel. Stress is laid on this particularly because there is still a large and unreasonable prejudice in certain quarters against the use of steels which have to be put in special condition, or more plainly, heat treated, before they are capable of doing their best work. Of course, as we all know, this feeling is largely giving way before the splendid performance which steels of this character are giving in service, and given

sufficient time, the special steels themselves will demonstrate the unsoundness of this objection, based largely upon the limitations of the older simple carbon steels.

One of the principal effects produced in steel by the addition of chrome-vanadium, is to raise the temperature at which the carbides dissolve in the iron, and the temperature at which they are precipitated out of solution. This elevation of the solution temperature is quite noticeable, the carbon content affecting this temperature but slightly.

It is unnecessary to point out the practical utility in commercial practice of working with a steel, in which this slow rate of transformation can be taken advantage of by the use of higher temperatures without resulting injury to the product, and also by the fact that the steel can stand exposure at these higher temperatures without the attendant harmful effect characteristic of other steels subjected to the same conditions. In fact, chrome-vanadium seems to attain its greatest combination of desirable qualities at higher treatment temperature than would be expected from the location of its critical range, due principally to the greater length of time necessary to effect the complete transformation of its constituents into a uniform and homogeneous solid solution. This point is emphasized because certain other commercial alloy steels, although excellent in many respects, have very narrow limits of annealing and hardening temperatures, and therefore require unusual care in their treatment, a slight deviation from the correct temperatures resulting unsatisfactorily.

A single quenching and drawing treatment, is sufficient for general purpose to effect complete refinement and hardening of chrome-vanadium steel. This characteristic of simplicity in treatment obviously insures a high-grade product under ordinary commercial conditions, and when compared with the double and triple heat treatments required for the refinement of other alloy steels, the economy presented is obvious. These properties, possessed only by the chrome-vanadium alloy, characterizes this steel as a material universally applicable for any commercial requirement. They also simplify the treating instructions necessary to successfully handle alloy steel of this chemical composition. One heat treating specification is adaptable for any carbon analysis, whether the steel is destined for case-hardening purposes or for oil-treating for gears and cones, etc. It has been found by experience that a temperature of 775 degrees C., which is suitable for hardening a case-hardening steel and still retain desirable toughness of the core, can also be employed for hardening oil-treated parts.

The lower-carbon chrome-vanadium steels are apparently pearlitic in nature and, as such, possess the increased strength and hardness resulting from the effect of the special elements in producing a ferrite of superior strength, subsequently resulting in a more dense and improved pearlite. With the increase in the carbon and alloy contents, this steel becomes more or less cementitic and it is probably this quality which demands the use of higher temperatures than usual in treatment in order to produce complete absorption of its component parts.

The quality of chrome-vanadium steel often described as "tough hardness" is one of its especially desirable properties, and is due probably to the somewhat finer and denser structure of the microscopic constituents, and to their more uniform distribution. This effect is ob-

tained not only through the actual influence of the chromium and vanadium as component parts of the alloy, but also to the influence of the combination of both of these elements in producing in the molten metal a condition of purity and freedom from gases, and, therefore, subsequently forming a metal which, at the time when the structural changes occur, is in the best possible condition for these changes to take place, that is, in the highest form in which the alloy composition renders it possible.

The adaptability of chrome-vanadium steel is general, and where strength and hardness and resistance to fatigue properties are the prerequisite, there is a chrome-vanadium steel for the purpose. When the steel is case hardened, a glass-hard surface and tough fibrous core is easily obtained. These properties are obtained without complex treatment, consisting of simple quenching, with reheating and quenching. For other heat-treated parts, a simple heating, quenching and drawing gives a steel, relatively so tough and strong, that it is unlike any other hardening alloy steel. Chrome-vanadium steel is a universal alloy steel and stands forth unmistakably as the master alloy.

QUESTION 44. *Is it advantageous for the purchaser to conduct a test on various brands of high speed steel before deciding upon placing his contract?*

QUESTION 45. *What is the value of testing finished tools with a file?*

ANSWER. The value of the file test depends upon the quality of the file and the intelligence and experience of the person using it. The file test is not reliable, but in the hands of an experienced operator, gives some valuable information. The manufacturer of small tools from high-speed steel sometime carriers the file test to extremes. Almost every steel treater knows of numerous instances where a lathe tool which could be touched with a file has shown wonderful results as to cutting efficiency.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A. S. S. T.

A RECENT communication received from one of our members enclosed the photograph which is shown below and which was taken "somewhere in Ohio." This photograph is interesting from the point of view that there are other materials beside steel which are being case hardened and we are wondering just what the name of a Society covering this activity would

be. It is possible it would be known as the American Society for Stone Treating (A. S. S. T.) The process involved in imparting a surface hardness to stone truly must be quite interesting.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.

Detroit—Second and fourth Monday. For meeting place call W. G. Calkins, Sec'y. Detroit Twist Drill Co.

STANDING OF THE CHAPTERS

In the July issue of TRANSACTIONS was published the standing of the chapters as of June 1st. The list below shows the standing of the chapters as of September 1st, the gain in membership for July and August being included.

1. Chicago
2. Detroit
3. Pittsburgh
4. Philadelphia
5. *Cleveland
6. *New York
7. Hartford
8. Milwaukee
9. BOSTON
10. LEHIGH VALLEY
11. Indianapolis
12. *Syracuse
13. *ROCKFORD
14. *Worcester*
15. Cincinnati
16. WASHINGTON
17. *North West*
18. *Springfield*
19. **Tri City*
20. **Providence*
21. New Haven
22. Buffalo
23. Schenectady
24. St. Louis
25. Toronto
26. South Bend
28. Bridgeport
27. Rochester

*=Tied

The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on June 1st. Those shown in italics are not occupying as high a position as in the previous report. Those printed in regular type (i.e. Chicago) are occupying the same position as in the previous report.

The following comments are self-explanatory.

TO CHICAGO (1), and DETROIT (2).

Detroit showed a gain of 23 members during the time just passed and but 44 members separate this chapter from Chicago and first place. There are in the office at the present time 20 applications for membership whose dues have not yet been paid and consequently are not included in this list.

Detroit has a membership committee that is working very conscientiously and showing results. It is probable that Chicago will take warning and act accordingly.

TO PITTSBURGH (3), and PHILADELPHIA (4).

These two chapters are occupying the same position as on the last report, there being but 19 members separating Philadelphia from third position.

TO CLEVELAND (5), and NEW YORK (6).

New York showed a gain and is at the present time tied with Cleveland parts which couuld introduce complications. The greatest advantage in this

for fifth position but Cleveland is awarded the higher place because it occupied this position in the last report. With fall activities approaching for both of these chapters, it is possible that the next report will show a change.

TO HARTFORD (7), and MILWAUKEE (8).

Milwaukee next to Detroit showed the largest gain in membership for the time covered by this report. Its growth has been so rapid that at the present time it is but 7 members behind Hartford in 7th position. The new officers and Membership Committee of the Milwaukee Chapter will not be satisfied in holding a place in the second division but have set the first division as their goal.

TO BOSTON (9), LEHIGH VALLEY (10), INDIANAPOLIS (11), SYRACUSE (12), and ROCKFORD (13).

But 6 members separate Rockford in 13th position from Boston in 9th place. Lehigh Valley is but 1 behind Boston, Indianapolis but 2, while Syracuse and Rockford are tied for 12th place, the position being awarded Rockford because of priority. A little work on the part of the Membership Committee of these chapters would be conducive to wonderful results and give the chapter a higher standing.

TO WORCESTER (14), and CINCINNATI (15).

Cincinnati is occupying the same position as in the previous report while Worcester is occupying one position lower having been in position 13 in the former report. But 8 members separate these two chapters and there are other chapters in 16th, 17th and 18th that are within striking distance of this group.

TO WASHINGTON (16), NORTH WEST (17), SPRINGFIELD (18), TRI CITIES (19), PROVIDENCE (20), NEW HAVEN (21).

But 7 members separate New Haven in 21st position from Washington in 16th place. The Washington Chapter showed an advance from 20th to 16th position due to the members in the Baltimore Chapter being transferred to the Washington Chapter. Providence and Tri City are in a tie for 19th place, one preference being awarded to Tri City. All of the chapters in this group are very close together as far as the number of members are concerned and the next report undoubtedly will show a radical rearrangement.

TO BUFFALO (22), SCHENECTADY (23), and ST. LOUIS (24).

But 1 member separates Schenectady from Buffalo and but 4 members separate St. Louis from the leader in this group. Inasmuch as these chapters have just been holding their own during the past year, they are in line for a large increase in membership and with concentrated effort their positions are sure to be advanced.

TO TORONTO (25), SOUTH BEND (26), ROCHESTER (27) and BRIDGEPORT (28).

The positions of these chapters remain unchanged although they could easily, with a membership campaign, increase their number so that it would not be long before they would be occupying higher positions. These chapters are all located in cities capable of supporting larger chapters than they have at the present time.

CHICAGO CHAPTER

THE September meeting of the Chicago Chapter was held at the Chicago City Club on Friday the 29th at 8 o'clock. The subject for this meeting was entitled "Heat Treating in the Rockies" given by T. E. Barker of Denver. The Chicago Chapter had a very good turn out to welcome Mr. Barker with whom every member in Chicago was thoroughly acquainted, and who by his untiring efforts was responsible for the formation of the Chicago Chapter and also of the National Society. The welcome and reception that was given Mr. Barker was typical of the hospitality of the Chicagoans.

CINCINNATI CHAPTER

The Cincinnati Chapter held its first monthly meeting on September 2 in McMicken Hall, University of Cincinnati. The meeting was preceded by a "get-together" dinner which was served at 6:30 p. m. and at 8 o'clock some important business matters were transacted. Following this order of business an inspection of the testing laboratory of the University was conducted. Prof. Jenkins made some demonstration tests on material in equipment in his laboratory.

The Cincinnati Chapter has prepared an interesting program for the coming year which is to cover the following subjects: The Blast Furnace and Pig Iron for the Foundry; Metallurgical Furnaces & Fuels; Grading of Iron; Autogeneous Welding; Stainless Steel; Case Hardening; Inspection of Foundry; Automobile trip to the American Rolling Mills Company at Middletown, Ohio and the Annual Dinner and meeting of the Chapter.

From the list of subjects which was given in the program, Cincinnati should have a very instructive and profitable program for the ensuing year.

CLEVELAND CHAPTER

The first meeting of the Cleveland Chapter will be held on October 17 in Room K of the Cleveland Engineering Society Rooms. This meeting will be a business meeting including a report of the delegates to the Annual Convention.

DETROIT CHAPTER

The Detroit Chapter held its first meeting of the year on Monday evening, September 11 at 8 p. m. in the General Motors Building. Prof. J. F. Keller of Purdue University delivered a very interesting illustrated paper on "Why Steel Warps." As this subject has been of special interest to all engaged in the heat treatment of steel a very good turn out was the result of the announcement of this meeing. The discussion which followed Prof. Keller's paper was very interesting and brought out some very good points with reference to the warping of metals during or as a result of heat treatment.

The second meeting of the season was held at the Cass Technical High School on September 25 at which time, Mr. R. S. Archer of the Aluminum Company of America presented his very interesting paper

entitled "The Slip Interference Theory of Hardening." This paper brought out an interesting discussion and proved to be of intense interest to all those in attendance.

SOUTH BEND CHAPTER

The South Bend Chapter held its first monthly meeting September 12 at the Y. M. C. A. Following a short business meeting, Mr. V. A. Crosby presented a paper entitled "Manufacture of Gears" which brought forth a very interesting discussion which consumed fully one hour. Following this paper the delegates to the annual convention were appointed. They are as follows: Messrs. Al Johnson; J. A. Kingsbury and W. F. Newhouse.

ROCHESTER CHAPTER

The Rochester Chapter held its first meeting of the season 1922-23 on Monday evening, September 11th in the Rochester Engineering Society rooms. Mr. W. R. Shimer of the Bethlehem Steel Company presented an illustrated talk covering the "Manufacture of Steel." Mr. Shimer's paper proved to be highly interesting and instructive as shown by the discussion which followed. This talk was the first of the progressive meetings planned for this season dealing consecutively with Rolling, Forging, Carburizing, Tool Steels, Automobile Steels, Metallography, Pyrometry, Furnaces and Equipment.

ST. LOUIS CHAPTER

The St. Louis Chapter held its monthly meeting on Monday evening September 18th at the American Annex Hotel. The meeting was preceded by a "get-together" dinner served at 7 p. m. Mr. Francis B. Foley, Metallurgist, Bureau of Mines, Rolla, Missouri, presented a paper entitled "Annealing." Mr. Foley presented some very interesting thoughts on annealing and his paper developed considerable interesting discussion.

TRI CITY CHAPTER

The Tri City Chapter held its first meeting of the season on September 14th at the Davenport Chamber of Commerce. Mr. O. T. Muehlemeyer, Chief Metallurgist of the Barber-Colman Company of Rockford and Chairman of the Rockford Chapter, presented a paper entitled "Hardening Practice." As Mr. Muehlemeyer is an authority on heat treating his paper proved to be very instructive and brought forth some interesting discussion.

SPRINGFIELD CHAPTER

Springfield Chapter held its first meeting Friday evening, September 22nd in the Technical High School auditorium at which time a six-reel film entitled "Manufacture of Armco Iron" was presented. This picture was taken at the plant of the American Rolling Mills Company at Middletown, Ohio, and showed their manufacturing process from the ore to the finished product.

INDIANAPOLIS CHAPTER

The first meeting of the season of 1922-23 was held by the Indianapolis Chapter of the American Society for Steel Treating, in the di-

rectors' room of the Indianapolis Chamber of Commerce, on Monday September 11th.

A short business session was held during which the tentative program was outlined for the season following. It is the intention of the program committee to vary the program this year somewhat. Every other month Indianapolis Chapter is to have one of its members speak on the local industry which he represents. This is done in the endeavor to inform the other members as to the progress of the industry in our home plants. The other months will have out of town speakers who it is hoped can be induced to talk on the manufacture of steel, starting in the first month with iron ore and continuing every other month thru the many processes in the steel industry. Mr. J. Weaver Smith, Industrial Engineer of the Citizens Gas Co., of this city invited the Chapter to an inspection trip for its January meeting at the local gas plant to see the manufacture of coke ending up with a dinner given with the compliments of the Gas Company.

The meeting was then turned over to Mr. H. E. Haywood who by means of Lantern slides, conducted a very interesting tour thru the Link Belt Co., plant and explained the interesting points of design and manufacture of Silent Chain.

The meeting adjourned until the next meeting which is to be Oct. 9th.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter has announced its program for the coming year starting with their September meeting which is to be a "Get-together" picnic on the 9th.

In October there will be two meetings, one in Bethlehem, the subject being "Pyrometry" and the other being in Detroit—the International Steel Exposition and Conventions.

In November the meeting will be in Bethlehem in connection with the Lehigh Valley Engineering Society, the address being by a prominent engineer.

The December meeting will be in Easton with the subject of the meeting "History and Application of Chemistry to Local Industries."

In January the meeting will be in Bethlehem on the subject of "Metallography."

The February meeting will be in Easton and will be a dinner meeting and the paper will be "A Talk on the Steel Industry" by a prominent engineer.

In March the meeting will be held in Bethlehem at which time the "Heat Treatment of Tool Steel" will be discussed.

In April the meeting will be held at Reading and the paper for this meeting will be the "History of Eastern Pennsylvania Iron and Steel Industry."

In May the meeting will be held in Easton at which time moving pictures of Steel Manufacturing Operations and the annual business meeting will be held.

In June the meeting will be held in Bethlehem the 14th and 15th—Eastern Sectional Meeting of National Society.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ARMITAGE, J. B., (M-7), 1084-39th St., Milwaukee, Wis.
BADGER, A. C., (M-9), 49 Parker St., Watertown, Mass.
BEACH, H. L., (M-9), 11 Hackfeld Rd., Worcester, Mass.
BENDER, C. P., (M-9), Studebaker Corp., South Bend, Ind.
BLOOD, B. H., (M-9), Pratt & Whitney Co., Hartford, Conn.
CHAMBERLAIN, V. V., (M-9), 722 Ave. H., Bethlehem, Pa.
CLARK, K. L., (A-6), 572 W. Randolph St., Chicago, Ill.
COLLINS, E. F., (M-9), 1926 Fullerton Ave., Detroit, Mich.
COLLINS, H. N., (M-9), Continental Motors Corp., Muskegon, Mich.
CRUICE, J. J., (A-8),1458 Lawrence Ave., Detroit, Mich.
DALRYMPLE, (M-9), 1407 Washington St., Easton, Pa.
DIETRICH, J. A., (M-9), 5656 Rogers St., Detroit, Mich.
DILLARD, J. B., (M-9), Cleveland Twist Drill Co., Cleveland, Ohio.
E. I. DUPONT de NEMOURS & CO., (Sb.-10), Wilmington, Del.
EHMAN, PRESTON, (Jr-9), 320-14th Ave., Newark, N. J.
GRIFFEN, R. J., (M-8), 2622 Lawndale Ave., Flint, Mich.
HAGLUND, P. E., (M-9), 223 Pasadena Ave., Highland Park, Mich.
HAYES, DR. ANSON, (M-9), 320 Stanton Ave., Ames, Iowa.
McELROY, L. T., (M-9), Standard Automatic Products Co., Corry, Pa.
McKEOUGH, J. J., (M-9), 8794 Quincy Ave., Detroit, Mich.
MURDEN, C. S., (M-6), 4916 N. Kedzie Ave., Chicago, Ill.
NICKEL, F. W., (M-9), Bowen Prod. Corp., Detroit, Mich.
REED, E. L., (M-9), 19 Westmoreland Ave., Arlington Heights, Mass.
ROYCE, F. E., (M-7), 1200 N. Main St., Detroit, Mich.
SMITH, F. W., (M-9), 518 Ave. "L," Bethlehem, Pa.
STEVENSON, G. I., (A-9), 2533 Broadway, Cleveland, Ohio.
STILWELL, E. W., (M-9), 480-9th St., Royal Oak, Mich.
STOLL, J. H., (Jr-9), 602 West Broad St., Bethlehem, Pa.
STUART, C. W., (M-7), 52 Garfield, Detroit, Mich.
SYLVESTER, N. J., (M-9), 345 Ave. "K," Bethlehem, Pa.
THOMAS, E. A., (M-8), 9771 Chenlot Ave., Detroit, Mich.
URSHEL, J. M., (M-10), Universal Machine Co., Bowling Green, Ohio.
WALTZ, W. H., (M-9), 227 W. Broad St., Bethlehem, Pa.
WARD, W. J., (M-10), 23 W. Congress St., Corry, Pa.
WELLS, F. O., (M-9), F. O. Wells Co., Greenfield, Mass.
WENK, E. O., (M-7), 1200 N. Main St., Ann Arbor, Mich.
WILLIAMS, C. C., (M-9), Bowen Products Corporation, Detroit, Mich.
ZUEGE, D. C., (M-8), Sivyer Steel Casting Co., Milwaukee, Wis.

CHANGES OF ADDRESS

ARTHUR, W., (M-12), from Reeds, Mo., to Texas Christian Univ., Fort Worth, Tex.
BECKER, M. E., from Winsor Ave. to 329 Church St., Hartford, Conn.
BENDLEY, W. P., (M-12), from 2384 E. Grand Blvd. to 544 Harper St., Detroit.
BORNSTEIN, H., (M-12), from 636-10th St. to C/o Deer & Co., Moline, Ill.
CARTER, H. G., from Florence Ave., Pittsburgh to 9038 Prospect St., Orange, Mass.
CHAMBERS, A. A., (M-5), from 225-32nd St. to 573 Superior St., Milwaukee, Wis.
GOODRICH, R. H., from L. M. Axle Co. to 1924 E. 105th St., Cleveland, Ohio.
GUISWITE, R. D., from Park Ave. to 2455½ N. Delaware St., Indianapolis, Ind.
LaFORE, P. J., (A-11), from West St. to 149 Tremont St., Boston, Mass.
MOREY, J. B., (M-2), from Crucible Steel Co., Dunkirk, to 127 Summit Ave., Buffalo, N. Y.
NILSON, H. T., from Ridgeway, Chicago to 1828 S. 48th Court, Cicero, Ill.
OSTERLUND, B., (M-4), from 4538 Wayne Ave. to 1733 W. Wingohocking St., Philadelphia.

PELOT, J H., from Dover, N. J., to 329 Park Ave., E. Orange, N. J.
REED, B. F., from Cramer St., Milwaukee, to 368-2nd Ave. Wauwatosa, Wis.
ROSEN, J., from Harms Hotel, Rock Island, Ill., to Rosen Machine Works, 126 Front St., Davenport, Iowa.
SMITH, L. A., from E. Market St. to Box 25, Scranton, Pa.
STEVENSON, F. L., (M-11), from Prospect Ave. to 2121 St. Clair Ave., Cleveland.
SWANBERG, C. G., (M-11), from Decatur, Ill. to 101 School, Geneva, Ill.
WIGGINS, C. R., from Flint, Mich. to 915 Eureka St., Lansing, Mich.
WILLIAMS, G. A., from E. 146th St., Cleveland to 20 Seymour St., Fredonia, N. Y.
WOODWARD, A. F., from E. 65th St. to 6205 Kinsman Rd., Cleveland, Ohio.
WYZALEK., J. F., (M-11), from Kearney, N. J., to 284 Argyle St., Arlington, N. J.
YEOMANS, L. I., from 1308 Monadnock Bldg. to 962 Monadnock Bldg., Chicago, Ill.

MAIL RETURNED

HARTMAN, FRED, N. E. Electric Company, Rochester, N. Y.
MILLER, C. C., 2427 Fourth St. N. E., Minneapolis, Minn.
MILLER, J. K., 531 Franklin St., E. Pittsburgh, Pa.
SMITH, J. R., 13 Washington St., Armor Park, Charleston, W. Va.
SPACE, J. H., Ludlum Steel Company, Philadelphia, Pa.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

REPRESENTATIVE-SALESMAN. Eight years experience in selling steel products such as alloy and tool steels, bars, plates, shapes, axles, wheels and tires, and miscellaneous forgings. At present in charge of sales of forgings, wheels, tires, tool and alloy steels in the Pacific Coast Territory for large steel concern. Would like to correspond with steel company desiring a capable representative on the Pacific Coast. Address 10-1.

METALLURGIST or CHEMIST. Exceptionally good experience together with a record of absolute satisfaction. Available at once. Eastern location preferred. Address 10-5.

CHEMIST and HEAT TREATER. Technical graduate. Experience in chemical, physical testing and heat treating of steels. Eastern location preferred. Reasonable salary. Address 10-10.

WANTED by a practical man with 22 years' experience with some leading firms of the United States, position as Supervisor or foreman of Heat Treating. Address 8-5

ANALYTICAL CHEMIST thoroughly familiar with the analysis of steel and steel works materials. Write, stating age, experience and salary required. Address 10-15.

GRADUATE CHEMIST who has had several years' experience in metallurgical analysis, analysis of iron and steel, etc. His work will be for the present, at least, wholly analytical. Address 10-20.

YOUNG MAN with four years experience in the heat treatment of steel and who has taken a course in metallography, wishes a position with some concern where there is a chance for advancement. Best of references. Address 9-1.

UNUSUAL opportunity to secure exclusive sales agency for tool steel mill in Detroit and Los Angeles districts. Mill long established and products of proven quality. Would require experience in selling steel and moderate capital. Address 9-15.

POSITIONS OPEN

POSITION OPEN as Assistant Metallurgist with large plant making bearings. College graduate with some years practical experience in heat treating or steel mill work preferred. State in reply education, experience, and salary desired. Address 9-5.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specializvd in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-13.

Reviews of Recent Patents

1,427,121. Heat Treatment of Manganese Steel. Wesley G. Nichols, Chicago, Ill., assignor to American Manganese Steel Company, Chicago, Ill., a Corporation of Maine. Filed Sept. 18, 1920. Serial No. 411,250. 5 Claims. (Cl. 148-13)

1. An improvement in the art of heat treating manganese steel castings, which consists in subjecting such castings to heat, the maximum temperature of which never exceeds the critical temperature of such castings.

1,427,319. Apparatus for Annealing Thin Steel Sheets. Samuel Peacock, Wheeling, W. Va., assignor, by mesne assignments, to Wheeling Steel & Iron Co., Wheeling, W. Va., a corporation of West Virginia. Filed Nov. 9, 1920. Serial No. 422,814. 2 claims. (Cl. 148-16.)

1. Is an apparatus for annealing thin sheets of steel, the combination of a metal base plate, a mass of refractory non-heat conducting material carried by said base plate; means for supporting said steel sheets in packs on said mass; a heat insulating cover comprising a plurality of metal members spaced apart and provided with air spaces between them; enclosing said mass and packs of sheets; means to form an airtight joint between said base plate and said cover; means to exhaust the air from around said packs; and electric heating means for heating said packs to an annealing temperature, substantially as described.

1,427,390. Apparatus for Use in Annealing or Otherwise Treating Metals. Alfred Howgate, Keighle, England. Filed Feb. 25, 1920. Serial No. 361,172. 4 claims. (Cl. 266-5.)

1. In the annealing of metals, a pan for the reception of the articles to be treated, detachable framework supported by said pan, and refractory material supported by said detachable framework.

1,428,534. Steel and Iron Alloy. Philippe De Clameey, Boston, Mass., assignor to B. F. Sturtevant Company, Hyde Park, Mass., a corporation of Massachusetts. Filed Oct. 6. 1919. Serial No. 328,685. 2 claims. (Cl. 75-1.)

1. An alloy of iron or steel, containing over 1¼ per cent and less than 6 per cent of cobalt, over ½ per cent and less than 6 per cent of chromium, over ¾ per cent and less than 7½ per cent of nickel, and over ½ per cent and less than 3 per cent of silicon.

1,428,637. Yield-Point Detector. Morton C. Hutchinson, Woodbury, N. J., assignor of one-half to Leon G. Buckwalter, Merchantville, N. J. Filed Feb. 26, 1919. Serial No. 279,368. 10 claims. (Cl. 73-51.)

1. In a device of the character described a body portion, an arm carried thereby and provided with a point to engage the specimen to be tested, a second arm pivoted upon the body portion and having a point to engage the specimen, means to hold the device in place while in use, and circuit closing means operated by the pivoted arm.

Commercial Items of Interest

THE Bristol Company of Waterbury, Connecticut are now distributing a 68-page catalogue devoted to Bristol Pyrometers. This catalogue is profusely illustrated and contains valuable condensed information on this subject. The catalogue is No. 1401—Bristol Pyrometers—and is available to any who desire it.

The Chicago Flexible Shaft Company announce that they have opened a new district sales office with headquarters in Indianapolis, for the purpose of better handling of furnace sales and Stewart Engineering service in Southern Indiana, Southern Ohio and Western West Virginia.

Mr. F. W. Odemar is in charge of this office and the address is 305 Merchants Bank Building.

Raymond K. Bowden, of Niles, Ohio, has been appointed Instructor in Metallurgy, for 1922-23, at Carnegie Institute of Technology, Pittsburgh. Mr. Bowden is a graduate of Ohio State University, in the class of 1920, with a bachelor's degree of Engineering in Mining. His practical experience covers two years as Superintendent of Inspection with the Central Steel Company, at Massillon, Ohio, and one year as Assistant to the Heat Treater at the Crucible Steel Company in Pittsburgh.

The Department of Metallurgy at Carnegie Tech was recently selected by the United States Naval Academy as its graduate school of metallurgy. Beginning this year, two officers from the Naval Academy have been assigned to take up advanced work in metallurgical subjects at the Pittsburgh institution.

H. M. Boylston, Professor of metallurgy Case School of Applied Science, has announced that for the third season he will conduct an evening course in the study of metallography and the heat treatment of iron and steel.

The course consists of twenty lessons to be given in ten weeks beginning Monday, October 16th, 1922. The class will convene at 7:00 P. M. in the metallurgical laboratory of Case School and will adjourn at 10:00 P. M. A thorough grounding in the principles of the subject will be given and considerable laboratory work will be undertaken, through which a good knowledge of heat treatment, metallographic preparation, microscopic examination and photomicrography may be secured.

It is announced that a college training is not necessary for those desiring

to enroll but it is suggested that those who have not previously studied the metallurgy of iron and steel review an elementary publication on iron and steel for a general knowledge of this subject as a back-ground.

Professor Boylston is well known in the metallurgical field and has been associated for many years with Prof. Albert Sauveur of Harvard University. He is a member of the American Society for Steel Treating being chairman of the Cleveland Chapter.

For further information relative to this course one may apply to Prof Boylston, Department of Metallurgy and Mining Engineering, Case School of Applied Science, Cleveland.

A romance of education for and in industry that can carry a lesson to nearly every American business center or industrial interest has been going on in Pittsburgh in recent years, and is today unfolding in a startling way.

It is built upon the fore-seeing genius of the great industrialist, Andrew Carnegie, and centers in the night work of the Carnegie Institute of Technology—an institution which, in effect, has become a great university for industry and the arts, functioning in the center of one of the world's foremost industrial regions.

The romance is in the knitting into one close practical texture of the educational and the industrial elements of an entire district, in a way directly and often amazingly vivifying the life of almost every natural resource, converting and manufacturing business that can be named. Ultimately, it will result, according to Dr. Thomas Stockham Baker, Acting President of the Institute, in the maintaining in Pittsburgh of the world's greatest research laboratories.

Stated elementally, workers of Pittsburgh—skilled and unskilled—have the fortunate, but by no means singly exceptional opportunity of obtaining additional technical training at a great college. There are other American cities where the same thing holds true. But upon this elemental, fortunate circumstance, a system of night education in, and for industry, has been built that touches practically every phase of industrial life. In, from shop girl to chief engineer, the effects of this system are today apparent, in hundreds of cases. The cumulative benefits to Pittsburgh in increased efficiency and general progress have been said by corporation heads to be incalculable.

In terms of the human equation, its results are that, through the medium of the Night Courses at the Institute, hundreds of ambitious youths each year are started on the road to increased earning power, and, in many cases, toward executive positions in their particular fields. But the outstanding feature of the Pittsburgh night courses in this respect is that many of its students go beyond the minor executive positions and become prominent business men, engineers, and professional experts. Its accepted value for this reason, to industry in the Pittsburgh district, is reflected in the regular

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annual action of many companies in encouraging both their younger and their college trained employes to enroll, and, often these students are assisted financially by their employers. The technical level of proficiency in the Pittsburgh district today, on the authority of Dr. Baker, is traceable directly and singly, in many cases, to some one man or group of men in high positions who have obtained their training in the Technology Night Classes.

One of the high spots of the Night Courses is their flexibility. No matter how limited may be the previous education of a young workman, he can get a start. If he wished a general technical training in any field he can get it. If he wants to specialize, he can do so. Special short courses are given to students seeking training in some one subject. On the other hand, a student can earn his collegiate degree in various fields in these same night courses. High school graduates are particularly interested in this opportunity, and a large number has already been graduated with bachelor degrees in various important engineering night courses, and have immediately advanced to more effective employment in their various specialized fields with a resulting increased stimulus to Pittsburgh industry as a whole.

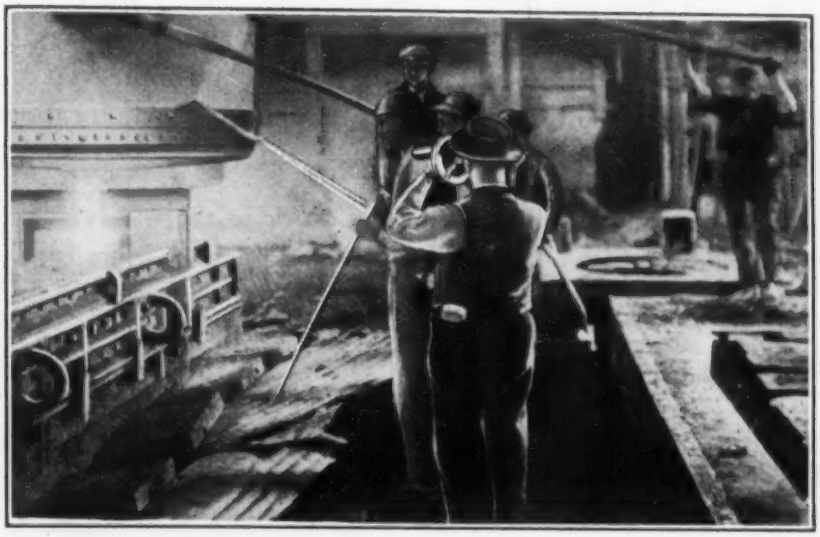
Still another source of students, almost unknown elsewhere in technical night courses, is the college graduate. Various advanced classes in engineering fields, chemistry, and other branches of science are organized each year to accommodate college graduates desiring additional training. These students often combine the practical problems of their daily work with the practical and theoretical work of the night courses to the individual advantage of their employing companies and, not infrequently, of a whole industry.

As a matter of fact, the establishment of the Institute in 1903 by Andrew Carnegie as an industrial school for the benefit of ambitious boys marked the beginning of an educational development, the remarkable significance of which to America, no one, probably, realized at the time. Its purpose was, possibly, in a somewhat general way, to help young men to greater technical training, so qualifying them to increase their earnings. Now, of course, in less than 20 years, the Institute has also taken its place as a great American college, in which both day and night students share in the use of one of the country's educational wonder-plants—the practical laboratories and shops at Schenley Park.

Hundreds of thousands of dollars have been expended, under Mr. Carnegie's endowment, to equip the Institute throughout with the most modern and efficient facilities, and the equipment of these laboratories and shops, alone, represent a substantial part of the entire investment. Technical experts and industrial leaders, both can learn things of profit from this great equipment.

Most of the Pittsburgh Night Students enroll in the College of Industries, where the variety of courses offered is large, and where the educational

POURING TEMPERATURES



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requirements for admission are more lenient. In the Building Trades, the subjects taught are Plumbing, Carpentry, Bricklaying, Sheet Metal, Electric Wiring, Structural Drafting, Building Trades Drafting, Heating and Ventilating, Concrete Work and Masonry, Plan Reading and Estimating. In the Machinery Trades are given courses in Foundry Work, Forging, Patternmaking, Machine Shop Practice, and Heat Treatment of Steel. Additional courses include Telephony, Practical Chemistry, Mechanical Drafting, Stationary Engineering, and Printing. Special courses for teachers in Industrial and Manual Arts are important fields of service, also, and many short vocational courses are included in the curricula.

The College of Engineering, where the work is more advanced, gives instruction in Chemistry, Civil, Electrical, Mechanical, and Metallurgical Engineering.

In Architecture, Painting and Illustration, Applied Art, Music, Drama and Sculpture, a wide variety of courses is also given that taps a large reservoir of uncultured talent and ambition. Many of the students in the Fine Arts College work in offices, stores, and other non-technical occupations attend Carnegie Tech in the evenings to have their artistic talents and inclinations developed.

So, in either its technical or its art courses, the night courses of the Institute, literally are serving industry in almost every phase—and serving it successfully.

The Universal Burner Co., Logansport, Ind., recently organized to manufacture oil burners and oil burning devices, is selecting a site for a new plant. Allen Nelson, Logansport, heads the company.

Dr. G. B. Waterhouse has accepted the appointment as head of the department of metallurgy at the Massachusetts Institute of Technology, Boston, and will assume his new duties at the beginning of the coming college year.

Dr. Waterhouse for the past 16 years has been connected with the Lackawanna Steel Company of Buffalo, N. Y. He is a member of the American Iron and Steel Institute, the Iron and Steel Institute (British) the American Institute of Mining and Metallurgical Engineers.

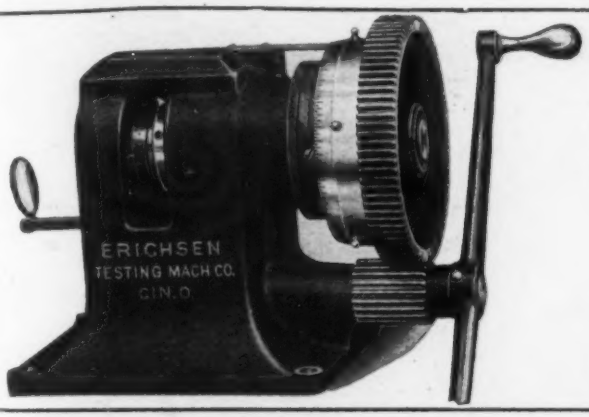
In his new work Doctor Waterhouse will succeed Prof. H. O. Hofman who resigned last June as head of the Metallurgical Department of the M. I. T.

The Quigley Fuel Systems, Inc., 26 Cortlandt Street, New York City, have recently issued Bulletin A which gives a condensed description of the Quigley Powdered Coal System and Appliances.

In this bulletin the lay-out of a typical coal milling plant is shown and the method of fuel distribution and control is briefly described.

The Westinghouse Electric & Mfg. Co., Pittsburgh, has leased space of the Bridgeport Engineering Co., for the establishment of a service and repair plant for the Naugatuck Valley district.

L. D. Canfield, district sales manager in charge of the New York territory, will be in charge of the new plant.



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To the Members

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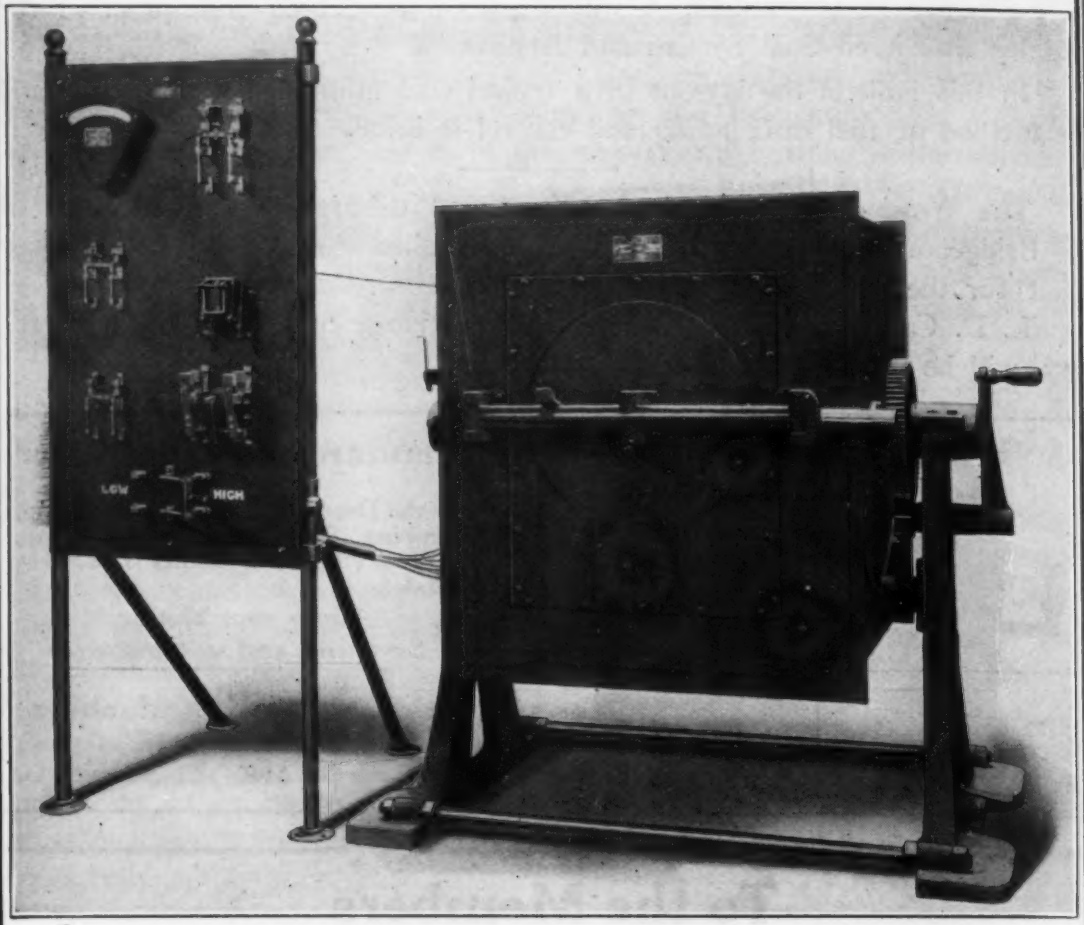

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